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ASSESSMENT OF FATIGUE IN AVIATION CREWS

by

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Assessment of Fatigue in Aviation Crews

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ABSTRACT

This study investigated the relationship of Schonpflug's model of regulatory behavior and a questionnaire which was designed to assess behavioral change due to fatigue in aviation crew members. Data was gathered from three patrol aviation squadrons. Rotated factor analysis was used to determine designation of factors and their related questions. A paired sample t-test was utilized for the determination of change due to a one month period of flight operations. The two statistical tests were graphically combined and compared to Schonpflug's model of regulatory behavior. The psychological costs to benefits economics of Schonpflug's regulatory model were confirmed. Schonpflug's model was found to be an excellent evaluative tool when coupled with the questionnaire's statistical tests in determining non resolution of problems brought about by fatigue.

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I. INTRODUCTION

Alert action by Naval forces is essential to the efficient operations of aircraft, ships at sea and shore establishments in times of national emergency as well as periods of normal operations. Alert action can save lives and assets. Fatigue effects the ability of personnel to maintain a high degree of alertness. Therefore, fatigue is a factor in the readiness of personnel when alert action is required over a period of time.

The importance of knowing the level of fatigue in personnel cannot be over emphasized. For example, well trained troops in World War II experienced an increasing number of cases of "battle fatigue" after long periods of physically demanding operations. It is important to note that training and corrective discipline did decrease the number of these cases but not to the point that fatigue was not a major factor in personnel readiness. Fatigue was directly correlated to the number of personnel being overcome by "nervous exhaustion" during the rigors of war. (Roberts, 1945)

Nervous exhaustion, an extreme of the normal levels of fatigue, can cause a severe degradation in the performance of personnel. More normal levels of fatigue can cause a lowering of productivity and a decrease in margins of safety

during critical missions. The ability to accurately assess the levels of fatigue in a group of individuals will allow planners to increase production and minimize loss during training exercises or in the event of war. A clearer assessment of the capabilities of personnel will improve the ability of planners to optimize and set realistic goals for training exercises. In times of war a clearer assessment of the capabilities of personnel will allow for realistic planning, which will reduce casualties and increase efficient use of available resources.

The excellence of Navy wide safety programs has resulted in a reduction in the loss of Naval personnel and assets. These reductions have proven that safety has a definite correlation with increased efficiency and control over assets. The Navy's emphasis on improving these safety programs is responsible for maximizing the use and effectiveness of available resources. A method to clearly assess the status of personnel, with regard to fatigue, is in keeping with this Navy policy.

In order to more fully recognize the importance of assessing the fatigue of personnel and how fatigue can effect the status of personnel, the following study will discuss the relationship between fatigue and accidents. This will be followed by a section that explains the relationship between fatigue and performance.

A. ACCIDENTS

A 1983 study of Naval aviation mishaps for fighter and rotary wing aircraft, reported a significantly greater incidence of pilot error in class A mishap (Intent for flight with destroyed aircraft, fatalities, permanent total disabilities or at least $500,000 of property damage) occurred if pilots had worked 10 hours during the 24 hours preceding the mishap. A further finding indicated that mishap rates were also significantly related to the time of day of flight operations. Rates of class A mishaps tended to be low for the hours between 0900 and 1800.

> Flights that originated between the hours of 0600 and 0900 as well as between 1800 and 2100 had high mishap rates for the TACAIR community, while the 1800 to 2100 period was high for the helicopter community. (Borowsky, 1983)

A causal relationship between fatigue and accidents is very difficult to establish. This study is significant in as much as the study establishes a relationship between fatigue and safety of flight. The three fatigue factors that were discussed in this study were circadian desynchronization, sleep deprivation, and work load prior to the flight. All three elements of fatigue have been shown to have a significant effect on performance during controlled tests. (Naitoh, 1968, pp. 1-13) (Kline, 1979, pp. 1-4) (Zinhenko, 1984, pp. 1-73) A better understanding of the elements that make up the overall state of fatigue has allowed investigators to assess the relationship between these

elements of fatigue and the occurrences of accidents in the field. This has brought about some causal inference between fatigue and aviation accidents.

A prominent point of view is that safety is in fact an ultimate criterion for evaluation of the effects of fatigue. Accidents are also synonymous with unsafe practices. The error in taking this approach is that safety is a relative commodity. The safety margins established for instrument flight rules are quite different from those established for arrested landings aboard an aircraft carrier. The decrement of performance brought about by fatigue is therefore relative to any of the numerous safety criteria for a given task.

The criteria that establish the procedures for an arrested gear landing leave very little tolerance for error. The exactness that is required is due primarily to the very narrow tolerances for a good trap or landing. This precision reduces the difference between an accident and a safe landing to seconds or a few feet. A small decrement in the performance of the pilot due to excess fatigue is very significant under the safety criteria established for a carrier based landing.

Fatigue has a close relationship with accidents on an aircraft carrier due to a very exacting set of safety criteria. Fatigue does not have as close a relationship to accidents in an environment that requires less precision.

Land based aircraft have approximately 10,000 feet of runway to negotiate a landing. A decrease in performance caused by fatigue may not have any effect on the number of accidents if there is a mile of runway to forgive any error in precision.

Fatigue and its relationship to accidents is hard to establish. Safety criteria vary widely due to less demanding levels of precision. This fact makes fatigue less easy to define, in terms of the number of accidents, due to forgiving environments which require less precise safety criteria. This fact does not dismiss the effects of fatigue on overall mission performance or completely remove fatigue as a contributor to aircraft accidents for any aviation community.

B. PERFORMANCE

Fatigue can degrade the effectiveness of personnel through the lessening of motivation, reduction in the ability to cope, lowering of aspirations, actual impairment and a lowering of competence. (Schonpflug, 1983, p. 317) This lowered effectiveness can be translated into a lower level of available human resources. During a military operation periods of greater than normal demand on the personnel may affect performance. Fatigue should not be ignored as a very important factor in planning for military operations.

A realistic approach to planning must consider the limitations of personnel to cope and be effective during prolonged periods of operational demands. The greater the demands and the longer the period, the greater the amount of degraded performance of the personnel involved. The need for a measure of performance degradation is therefore important to projecting the ability of the available manpower to meet operational commitments.

C. SUMMARY

The need for a greater understanding of the relationship of fatigue to human behavior has been established for very close to a century. Great military leaders have been keenly aware of the ability of their troops to overcome the undesired effects of fatigue by observing their morale. It is important to military leaders of this day and age to improve first the clarity of the definition of fatigue and secondly assess the dynamics of fatigue's effects on personnel.

This study uses as a starting point the definition that Bartley and Chute (1947, pp. 53-56) espoused in their early work of "Fatigue and Impairment in Man." The following list from Bartley and Chute (1947, pp. 53-56) gives as their definition of fatigue:

1. Fatigue and impairment are not identical. When both exist at once they can be separated.
2. Fatigue is not measured by measuring impairment.

3. Unlike impairment, fatigue is always directly experienced i.e., it is an experience.

4. Fatigue is part of an individuals stance toward activity attitude, maintenance of a posture, or the simple need to stay awake.

5. Fatigue is a manifestation of personal continuity. The immediate situation does not contain all the origins of the fatigue of a given moment.

6. Fatigue is personal. Fatigue pertains to the individual as a whole.

7. Fatigue is the outcome of conflict. When relief of bodily discomfort is prevented and action is thwarted, fatigue commonly develops.

8. Fatigue is not to be confused with boredom.

9. Fatigue is cumulative. Fatigue developed on one occasion is likely to be revived when a similar situation develops.

10. Fatigue's onset and recovery may be sudden.

11. The concept of fatigue pertains to organization. Fatigue is a kind of behavior of the organism which is to be understood primarily in terms of organization.

12. Fatigue does not crucially depend upon energy expenditure. Energy is of course involved, but the crucial determination of fatigue is organization.

13. Fatigue is never specific to a given body member.

14. Fatigue is not to be defined or analyzed in terms of its supposed origins, nor on the basis of function involved.

As per Bartley and Chutes'(1947, pp. 53-56) definition this study is not focused on subcategories of fatigue. The primary focus is intended to give a fuller view of the interrelationship of the individual's and aircrew's organizational or behavioral patterns. The goal is to take a field survey of three land based aviation patrol squadrons

and determine the interrelationship and levels of various performance related questions in order to assess the overall organization of fatigue.

This will be accomplished in two separate chapters. The background information in Chapter I will give a more thorough definition to fatigue and related categories. This background information will then be followed by an explanation and analysis of the squadron surveys in Chapter II. In order to accomplish this analysis a model will be used that represents the regulatory behavior of an individual. This model contains eight modes of regulation which operate simultaneously and in combination. (Schonpflug, 1983, p. 321) A further explanation will be given in Chapter I.

Fatigue is important to military operations. The small margins of error and necessity for very high levels of performance makes fatigue a factor in all operational planning and execution. Efficiency of personnel can make the difference between a victory or defeat in times of war especially in the high technology fields that are becoming more a part of the military each year. A better definition of the dynamics of fatigue will improve the Navy's overall preparedness for meeting the challenges of even greater demands on human performance. With these things in mind the following chapters are presented.

II. BACKGROUND

A wealth of information is now available regarding the subject of fatigue. At present the following categories have at one time or another been considered as factors in fatigue: circadian rhythm, stress, mental activity, physical activity, metabolism, nutrition, anoxia, heat stress, sleep decrement, cognitive work capacity, vision decrement, vibration and sleep patterns. This list represents a tremendous effort on the part of many individuals toward a definition and better understanding of fatigue. The principal problem facing any investigator is the tremendous number of variables and the variation within those variables.

Fatigue is very fundamental to the behavior of the human race. Fatigue is also very difficult to measure due to its subjective nature. This is due to the tremendous variation or adaptability that human beings possess. Fatigue is therefore a study based on a large number of uncertainties which makes a clear definition very illusive. Bartley and Chute (1947, p. 47) were very emphatic about the importance of the definition of fatigue. This emphasis on the importance of a definition for fatigue is at the core of fatigue's complex nature. Fatigue has not been fully defined after over seven decades of research. A short

history is necessary to improve the readers understanding of the efforts that have occurred in the search for a clearer definition of fatigue.

A. HISTORY OF FATIGUE

A review of the history of fatigue by Cameron (1973, pp. 633-634) gives a overall summarization of fatigue and related studies to 1973.

> Research into fatigue has passed through two major periods of interest and is now in a third. In the period during and after the First World War, basic research was carried out in England by the Industrial Fatigue Research Board. Its area of interest was productivity in industry, especially the munitions industry. Its reports, some of them classics which are still referred to, dealt with such matters as hours of work, both daily and weekly, shift change systems, illumination and ventilation, work place design and plant layout. The guiding theme of this work was the notion that the output of the worker was limited in some way by fatigue and that the alleviation of fatigue, by whatever means, would enable production to be maintained at a high level. . . . The second major wave of interest in fatigue effects occurred during the 40's and 50's. The focus of this work was aviation, especially military aviation. The classic work of Bartlett (1943), Drew (1940) and Davis (1946, 1948) dates from this period and employed more complex criteria than simple output figures. The patterns of breakdown in skilled performance which occurs in fatigue, and indeed under the influence of other types of stress condition, was clearly established as a result of this work. In 1947 . . . Bartley and Chute . . . made a much more thorough study of fatigue as an explanatory concept than any one before or since. The book emphasized the complex nature of fatigue and distinguished three basic facets to the problem. They considered that fatigue should only describe the subjective feelings of lassitude and disinclination for activity . . . and use the term impairment to identify the true reduction of physical capacity. (Cameron, 1973, pp. 633-634)

Cameron's (1973, pp. 633-648) insight and the insight of those that perceived the need to increase the length of

fatigue studies have produced an ever improving understanding of fatigue. The importance of increasing the length of fatigue studies has been demonstrated by the separation of cumulative fatigue and "reactive inhibition." It is important to discuss Cameron's (1973, p. 646) "reactive inhibition" concept because this concept is central to the issue of defining fatigue.

1. <u>Reactive Inhibition</u>

The term "reactive inhibition" is used to describe the type of short term fatigue or inhibition that can be completely recovered from in a single rest cycle. The effects or the type of fatigue that is of primary concern to Cameron and referred to by Bartley and Chute (1947, pp. 54-56) as "true" fatigue is the type of fatigue that is resistant to a normal process of recovery. "Reactive inhibition" is a condition that is caused by a normal state of work that is recoverable in a normal cycle and is expected when work is performed. "True" fatigue or cumulative fatigue is the accumulation of effects caused by days, weeks, or months of stress or work that resist the normal process of rest and recuperation. (Cameron, 1973, pp. 645-646)

2. <u>Cumulative Fatigue</u>

Cumulative fatigue is an accumulation of some residual effect. This residual effect is not recovered from during normal rest cycles and persists for some unknown

length of time. The levels of this accumulation grow if an interior or exterior stimulus is continued for an extended period. The levels of accumulation have no measure to date and the length of persistance is not known. (Cameron, 1973, pp. 643-646)

B. THE DEFINITION OF FATIGUE AND THE SURVEY DESIGN

The pursuit of knowledge in the area of fatigue should meet the requirements of the classic work of Bartley and Chute (1947, pp. 47-56) and extend over a length of time consistent with Cameron's (1973, pp. 643-646) criteria. In order to meet these criteria a field study of fatigue that utilizes many of the basic rules that were laid out by Bartley and Chute (1947, pp. 47-56), and Cameron (1973, pp. 643-646) was designed. An additional criteria for the studies design was to provide an improved understanding of the circumstances that a manager faces when confronted with dealing with fatigue symptoms in an aircrew. This additional criteria required a questionnaire that could be easily administered, could be given after the fact and covered a period of a month.

For most practical applications military managers must be able to assess the degree of fatigue in personnel from moderate to severe states. The first questionnaire (Appendix C) was designed for evaluation of fatigue in a Patrol aviation squadron that was experiencing close to severe levels of fatigue.

The initial questionnaire and the improved version (Appendix D) were intended to apply a total performance concept to the evaluation of fatigue. The objective was to be consistent with Bartley and Chutes (1947, pp. 47-49) assumptions and assess a spectrum of behavioral changes that are brought about by obvious fatigue conditions. The purpose was to identify the primary factors, establish the levels of change in each question, discover the integration between the primary factors and find some general explanations for the differences and similarities.

At this point a listing of Bartley and Chutes' (1947, pp. 47-48) assumptions can give a better conceptual design criteria for the questionnaire.

1. "Since, fatigue is taken to be an experience, it is an expression of the whole person. Theory, then, must attempt to handle it as such."

2. "We assume the organism to be a unity and not a plurality."

3. "In the present formulation, fatigue is regarded as an experiential pattern arising in a conflict situation in which the general alignment of the pattern arising from this conflict situation . . . may be described as aversion. The subjective constituents of this fatigue pattern are not to be taken an epiphenomena, or as symptoms of fatigue, but as fatigue itself."

4. "Adequate handling of fatigue requires a science of the person, i.e., a science over and above disciplines merely related to the person." (Bartley and Chute, 1947, pp. 47-48)

A more in depth discussion of the questionnaire will be given in Chapter II. The conceptual basis for the questionnaire is important at this point due to the

necessity of clarifying the definition of fatigue that is to be used for the thesis. The choice of a definition for fatigue is much like choosing a point of view toward a topic or problem. This point of view, like an opinion, need not have an defensible basis but a choice is necessary.

C. SELECTED STUDIES ON FATIGUE

Most of the investigations of fatigue have not successfully attempted to follow Bartley and Chutes' basic assumptions. The bulk of the research has broken into various sub categories or pluralities of fatigue but has not attempted to explain the experience of the whole person. The subcategories of fatigue mentioned earlier have stayed generally the same since the writing of "Fatigue and Impairment in Man" in 1947. The research in these various areas has improved the knowledge base for fatigue but not the overall understanding. Various studies have been able to establish some causal relationships that are valuable in understanding the workings and important elements of fatigue. The studies are much too numerous to list but a few examples of representative studies will aid in the understanding of the results of research on fatigue to date.

1. Schonpflug's Model of Regulatory Behavior

Schonpflug's (1983, p. 321) model is one of the exceptions to the general trend that has not dealt with the fatigue in a holistic manner. The primary emphasis of the studies conducted by Schonpflug (1983, pp. 303-313) deal

with stress not fatigue. The holistic approach of Schonpflug (1983, pp. 299-327) is one of describing a balance of psychological benefits and costs, which Schonpflug (1983, pp. 317-322) regards as the central issue for the regulation of internal states of stress and external stressors. This approach is holistic and requires a view point that is consistent over longer periods of time. This approach is also consistent with Cameron's (1973, p. 645) conceptualization of fatigue which consists of fatigue being a generalized response to stress that accumulates over time.

Schonpflug (1983, p. 321) has presented a model that meets the criteria of Bartley and Chute (1947, pp. 53-56). The model is described as a regulatory system that operates toward a maximization or minimization of psychological costs. This model will be used as a basis for the evaluation of many of the groupings of questions used in this study's questionnaires. A general description of this model is given in the following quotation.

> Different modes of regulation can be assumed to operate simultaneously and in combination. Benefits and costs for each mode will have to be calculated: a. Separately. b. In combination with other modes. c. With reference to external and internal conditions. d. For short periods of time. e. For more extended periods of time. Calculations of this sort should yield parameters for a trade-off between different modes of regulation and different combinations of modes. On the basis of these parameters behavior regulation may take place. Effective regulation will lead to minimizing psychological costs; poor regulation towards maximizing them. (Schonpflug, 1983, p. 321)

Figure 1 represents a model of the regulatory system operating toward minimization or maximization of psychological costs.

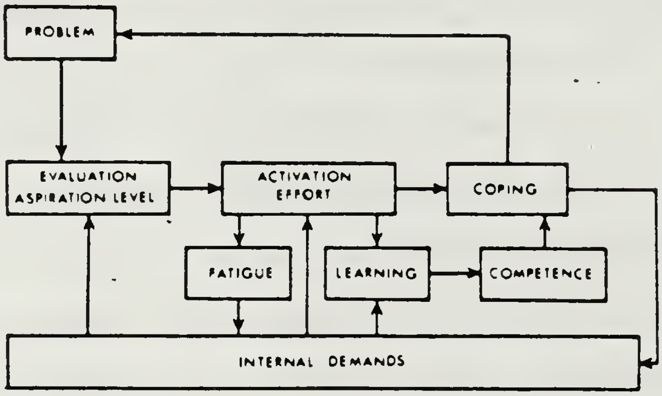


Figure 1. Schonpflug's Model of Regulatory Behavior

Figure 1 is the best model for explaining the interrelationships of a very complex system of behavioral change brought about by fatigue. The operations contained in this model do not explain the group dynamics associated with fatigue but the model does give a system from which external behavior can explain internal behavior or vice versa.

Schonpflug (1983, pp. 317-318) uses the analogy of limited resources and economics to explain the behavior of the internal demands portion of Figure 1. Resources are represented as energy pools that an individual can place demands upon, in times of greater than normal consumption.

The energy pool is limited and an allocation to various demands must be made to satisfy these demands. A rationing takes place when demands exceed supply. The strategies used are a lowering of consumption, calculations that expend energy toward only the most efficient and effective outcomes, and long term calculations that decrease output and distribute effort over time. The last strategy would be an attempt to normalize efforts and adapt to conditions.

Stress is viewed by Schonpflug (1983, pp. 304-306) as the primary outcome of the expenditure of the energy pool. Problem orientation and coping attempts as a result of outside stimulus, require greater than normal amounts of energy. Stress is then primarily the result of the energy demands that are brought about by the greater demands of energy expenditure due to problem orientation and coping attempts. If the problems are not resolved due to a lack of energy pool reserves the problem persists. The cycle of non recovery that Cameron (1973, p. 640) referred to is then occurring. Continued exposure to this stimulus augments the greater requirement placed on a non existent reserve and another cycle occurs. Problem orientation persist and coping attempts continue. This supports Cameron's (1973, p. 640) contention that fatigue follows stress.

Many of Schonpflug's (1983, pp. 325-326) assertions will be discussed in the analysis section of this thesis. Schonpflug's insights into the link between stress and

fatigue will be illustrated further in the analysis of the responses given to the questions during the analysis portion of this discussion.

As stated earlier many excellent studies have been conducted in recent years. The Psychometrics of fatigue gives another model that may aid in the analysis of the responses to the questionnaires.

2. <u>The Psychometrics of Fatigue</u>

The psychometrics of fatigue come very close to meeting the requirement of a theoretical framework of evaluation called for by Bartley and Chute (1947, pp. 47-51). The study deals primarily with "reactive inhibition" due to a concentration on the category of short term memory but the framework of the study and some of the results are significant to any study of fatigue. This study was conducted by V.P. Zinchenko, Yu. K. Strelkov, and A. B. Leonova originally published in Russian in 1977 and translated to English by Paul Pignon in 1984. The study develops the relationship of short term mental information processing and fatigue. The study dealt with short term memory through the use of a basic model of mental processes. This research attempts to examine the various stages of short term mental processes through reaction time, seeking a preassigned signal in a random sequence of numbers, recognition, reproduction, and determining the missing digit in a series of numbers. These test were varied in sequence

length and interval between stimulus. The overall objective was to measure the short term memory changes between the morning period prior to work and the afternoon period after a normal work day. The following discussion gives the reasons that Bartley's assumption for fatigue are in large part met by this study.

The behavior and performance of an individual must come from the perceptions of environmental stimuli and the ability of humans to process and act upon information provided by those stimuli. This dictates that human performance or the important functions of the whole person, limited by the clarity of perception, is primarily controlled by the mental facility of the human from which the task is forthcoming. If fatigue and the behavioral systems associated with fatigue are to be understood, the core of the research must deal with the human's information processing ability under fatigue conditions and the related decisions which are made under the influence of fatigue.

The assessment of the degradation of performance associated with fatigue should therefore have as its basis the change in mental capacity for information processing.

Information processing can best be described by Figure 2. A description of the definition for the various boxes is also listed. The boxes are representations of various parts of the short term information processing system of individuals.

1. The first box to the left of the diagram is the Sensory memory which has visual, motor and auditory input stages. The Sensory memory can be characterized by large capacity and short retention time.

2. The second stage of information processing is the filtering, recognition and recoding. This process transfers only a small portion of the sensory memory input through object recognition, color, size, shape, position in space or complex timbral characteristics such as those that distinguish male from female voices patterns.

3. The third stage of information processing is the primary memory unit. Its function is to store relevant task oriented information to permit further information processing. This can take the form of recall through the process of rehearsal and transfer to secondary memory.

4. Rehearsal processing, the forth stage, is used in order to minimize forgetting. Rehearsal accomplishes three tasks.

   a. Preservation of information in primary memory

   b. Transfer of information to secondary memory

   c. Preparation of response (method and strategy of grouping of data)

5. The fifth stage is the secondary memory. The Secondary memory is used for long period storage. Semantic processing is indicative of the Secondary memories function. Non verbal long term storage can also take place in this stage of memory.

6. The sixth stage of information processing is the memory scanning process. Memory scanning can best be characterized by trace recall. Trace recall utilizes scanning traces of a series stored in memory and compares them with stimulus from visual sensory memory.

7. The seventh stage of the process is the all important decision making process. This stage uses all the information available to conclude what is hopefully correct estimates of reality.

Figure 2 is presented below:

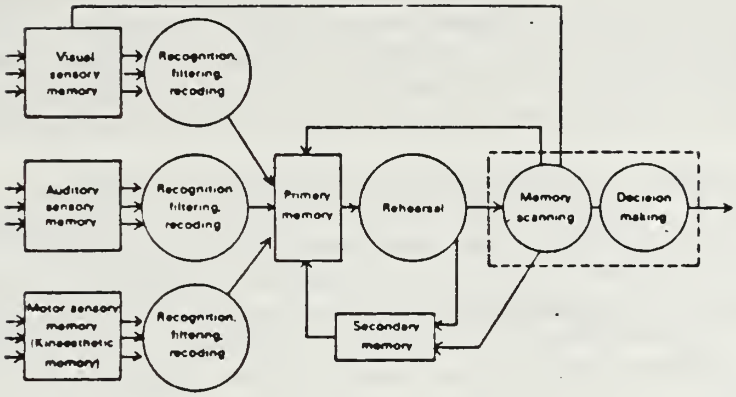


Figure 2. Model of Short Term Memory

a. Results

The results of the study are far reaching in the study of fatigue. The psychometrics of fatigue give direction to further research in the area of short term memory and the mind as a whole. The following list represents the purpose of each of a series of test carried out in order to (a) estimate quantitatively the stage of fatigue in relation to the functioning of each individual unit and of the short term memory system as a whole, (b) describe the dynamics of the change with in the model in terms of the change in each individual unit in the model, (c) indicate the units with in the model that are responsible for lowering the efficiency of the individual that is tested. The following list represent separate tests that are intended to test different parts of the mental model:

1. Reaction time was used to determine the latency of response to a stimulus for all tests. Measurement of this parameter enables the timing of different operations to be determined. It also distinguishes the differences in the mode of performance of a test.

2. The seek a signal in noise test required a subject to seek a preassigned digit within a sequence of random numbers that are serially presented. Pressing a button "yes" or "no" signaled whether the preassigned digit was present in a sequence. This test excludes the influence of primary memory and rehearsal units and determines only the time of retrieval from sensory memory.

3. In order to accomplish the recognition test the subject was presented a random sequence of digits followed by a digit and asked to determine if the digit was present in the preceding random sequence of digits. Recognition is not possible without prior transfer of information into primary memory. A combination of full reproduction and recognition determines the functioning of the primary memory unit and indirectly the degree to which the information is stored via the reproduction unit.

4. The determining the missing digit test uses a sequence of a section of the alphabet which is shown to the subject prior to the test. All of the letters except one are presented in a random sequence. The objective is to determine which letter is missing.

The determination of the missing digit is a complex task. It requires the memorization of all material presented and the transformation of the letters from a normal sequence. The performance of operations involved in logical transformation of information are tested by determining the missing digit.

5. The full reproduction test consists of presenting the subject with a series of digits. After the series is presented the subject is required to reproduce the same digits in any order. In order to get successful reproduction the information must be recoded and transferred to the primary memory unit. This test can determine the functioning of the primary memory unit and the response unit.

6. The full reproduction with an interfering task test is the same as the test above except that a simple interfering task is also given. The objective is to change the timing of the interfering task to test the time characteristics of the rehearsal unit.

The results of these tests indicate that the recognition, full reproduction and determining the missing digit are the most sensitive detectors of fatigue. The seek signal in noise test was suitable for assessing the functional state of the subject in a limited number of cases. Reaction time and full reproduction with an interfering task showed no significant change.

The greater load on memory, the more pronounced was the effect of fatigue. This was however; relative to the difficulty of the task. The inter stimulus interval was most effected by fatigue at times of up to 120 ms for seeking signal in noise, 90, 150-210 ms for recognition; 150-210 ms for full reproduction; and 180-360 ms for determining the missing digit.

In recognition and full reproduction tests, fatigue adversely effects the initial part of the memorized and recalled digits. Overall the percent of correct responses is the best indicator of fatigue due to the direct measure of working capacity. The reaction time to the sequence was more a measure of skill in the tasks and is not as direct a measure of performance. Both indicators are needed for a thorough investigation but are not equal indices.

The indication is that fatigue always affects the same operations, what could be called weak points in the system of information transformation.

> These affects include: prolonged storage in sensory memory; disturbance of operations of rehearsal and retrieval from primary memory; and disturbance of operations establishing semantic associations in secondary memory. There is relatively little change in the duration of storage in primary memory, and also in the operations of sensory processing and identifications of the single stimulus, transfer to primary memory and response. In acting as internal control for the routing of information in the short-term memory system, these operations essentially perform the function of attention. Therefore we may say that fatigue disturbs the performance of those operations which all for maximum mobilization of attention. (Zinohenko, 1984)

The indication that maximum mobilization of attention shows the greatest affect from fatigue, integrates well with the performance degradations that are discussed by Schonpflug (1983) and from various environmental stimulus studies. Is maximum mobilization of attention part of "reactive inhibition," or does maximum mobilization of attention have a direct correlation to the cumulative effects of fatigue?

Circadian rhythm, sleep deprivation, or stressors in general will require some adaptive processing. All environmental change requires adaptive functioning some level of over or under stimulation. The complexity of adaptation can be illustrated by Schonpflug's behavioral system Figure 1. Areas of the brain that are least able to accommodate the change or get the brunt of the work load will therefore experience overload. The change in the

ability to process data in the brain may be the best indicator of the actual status of various functional areas brought about by fatigue.

Environmental stressors may cause the areas of the brain that perform during maximum mobilization of attention to become over stimulated. This may cause shifts in mental processing to other areas or channels, increased insensitivity or lower responsiveness in brain cells over time (Welford, 1968, p. 261), or an increase in "neural noise" (Crawford, 1961). These mental models demonstrate that cumulative effects of fatigue may also be related directly to "reactive inhibition." The conflict within the organisms organizational structure that Bartley and Chute (1947, p. 47) referred may be confirmed by this study. The approach to fatigue from this perspective may yield a greater understanding of the dynamics of fatigue. It seems that an even more thorough understanding of the functioning of fatigue could be gained by future studies of this type that are of a longer duration. This should be done in order to determine which of the brains functions are receiving residuals which are not recovered from with normal amounts of rest and relaxation.

3. Sleep Deprivation

Naitoh (1968) described research that was conducted at the Navy Medical Neuropsychiatric research Unit, San

Diego, CA which will address the correlation of fatigue and sleep deprivation.

Experimental evidence indicates that short periods of sleep loss can cause visual and auditory misperceptions, disorientation in time, deficiency in short term memory, and minor changes in personality. The primary concern about sleep loss and its relation to cumulative fatigue is that of sleep debt. Alluisi (1964) demonstrated the critical role that sleep played in individuals performance. He found that abnormal work-rest cycles disrupted human efficiency and lowered reliability. After a 6 hour schedule of 6 hours on duty and 2 hours off, results showed severe performance degradation. The explanation for this change was that on such a schedule crew members averaged only four hours sleep per 24 hour period. This amount of sleep was far too short to sustain long term operations. A work rest schedule of 4 hours duty and 2 hours off resulted in 5.5 hours of sleep in a 24 hour period and allowed highly motivated individuals to maintain performance levels for two weeks.

The accumulated sleep debt is in many respects correlated to the same effects of cumulative fatigue. Both terms represent a non recovery from periods of activity. Both terms result in the degraded performance. High motivation can in both cases extend the period that performance goes unchanged. Fatigue is probably very highly correlated with sleep debt but they are not the same. The

difference is in recovery from effects. Fatigue theory has allowed for rapid recovery under an exciting or motivating circumstance i.e., a change to a pleasing environment. Sleep debt, even though stimulation from events can bring about higher levels of arousal, requires normal scheduled sleep periods to accomplish complete recovery. Sleep may bring about recovery from fatigue that is described by Cameron (1973, p. 646) as "reactive inhibition" but as per the definition given earlier cumulative fatigue is due to non recovery during normal rest cycles.

Cameron's theory of fatigue (1973, p. 646) refers to the need for studies to include recovery time as an index for the levels of cumulative fatigue. The understanding of fatigue's relationship to sleep would be greatly increased by a study that included a recovery index from fatigue through normal sleep cycles.

a. The Walter Reed Studies

In 1956, The Walter Reed group undertook a series of studies on sleep loss and performance. The objective was to construct tests that would be resistant to sleep loss and evaluate tests for there sensitivity to sleep loss. The results which represent a blend between fatigue and sleep loss produced four basic predictors. They are:

1. Sleep deprived subjects show brief intermittent lapses. These lapses increase in frequency and duration as sleep debt increases.
2. Certain factors may alter the subject, which prevent or shorten these lapses.

a. Massive sensory stimulation caused by physical exercise, electric shock, loud noise, adrenenergic drugs

b. Uncertainty

c. Feedback of information upon the quality of performance

d. Task change

3. Automatic response sequences are relatively resistant to sleep loss.

4. Many, tests are effected by diurnal rhythm. The Walter Reed lapse hypothesis came out of this study. The lapse hypothesis can best be described by:

> The lapse, in context of total sleep loss research, best summarizes a variety of situations in which there are absences of the motor responses needed to perform the task or there are intermittencies in motor performance. In other words, the concept of lapse would offer us a shorthand language for describing errors of omission, absence of adequate motor responses, and for describing responses with long reaction time. (Naitoh, 1968, p. 6)

The segregation of what is fatigue and what is sleep decrement in this study is not all together clear. Lapses are associated primarily with sleep loss in all the literature, however; the separation of sleep debt and fatigue has not been studied. The separation of the two phenomena would be difficult but if one assumes that fatigue is not totally dependent on hours of sleep or hours of sleep is not a factor in the degraded performance of a test then the separation may be possible. Which factors belong to fatigue and which to sleep debt may allow clearer definition of the terms. The factors that are sensitive to sleep loss are listed in Naitoh's (1968, pp. 11-13) monograph they are:

1. The longer the task is, the more sensitive it is to total sleep loss.

2. Total sleep loss of 30 hours did not appear to impair performance if the subject got feedback. The immediate feedback of the quality of task performance appears to minimize the effects of total sleep loss.

3. Performance of difficult tasks are more sensitive to loss of total sleep.

4. The self paced task can resist sleep loss better than the work-paced tasks.

5. Newly acquired skills are more affected by loss of total sleep than those skills which have become almost automatic or second nature.

6. The more complex a task is, in terms of a complicated chain of mental operations and or of an orderly execution of complex muscular activities, the more likely it is to be sensitive to loss of total sleep.

7. Any task which needs a short-term memory chin will be affected by loss of total sleep.

These seven factors that show sensitivity to sleep loss are also effected by psychological factors. These psychological factors are:

1. Interesting tasks resist the effects of loss of total sleep.

2. High motivation tasks, showed no degraded performance in the first night of sleep loss. Most of the low motivational tasks showed poor performance during the same period of time.

3. Extroverts were effected more than introverts by a loss of 60 hours of sleep.

4. Repeated experience of sleep loss increased the effects of such sleep loss on performance.

5. The severity of the effect of sleep loss depends on the time of day that measures are obtained. (Naitoh, 1968, pp. 11-13)

This rather long list is very similar to the list that would be included in a similar list for fatigue. Unfortunately no such list was found in the literature. The design of any test that would evaluate the sensitivity of fatigue to various psychological or behavioral stimulus would probably produce very similar results. The research on fatigue has not been as thorough nor has fatigue been separated from sleep debt. The two phenomena may be very close to the same in sensitivity toward task but indications are that they are also different in some very basic respects.

As mentioned before, decrements in performance brought about by fatigue can exist without the presence of sleep debt. There is also a separation of what is called "reactive inhibition" and cumulative fatigue mentioned earlier. Is sleep debt just a form of the residual which produces cumulative fatigue? It would seem that sleep debt is linked to fatigue but that fatigue is more related to stressors and that sleep debt is related more directly to lack of allowance for recovery and biological necessity. The separation of fatigue and sleep debt may not be totally practical but clarity of definition for both terms would definitely enhanced by a study that separated the two.

4. <u>Circadian Rhythms</u>

Circadian rhythms are often referred to as rhythms of the human biological clock. Changes in the time of day

that one performs a given task has been shown to have a great effect on human performance. This degraded performance has been explained as the desyncronization of the biological clock and has been referred to as one of the established categories that can contribute to "fatigue." The correlation between sleep debt and fatigue confuses their separation due to the complexity of both phenomena. Circadian rhythms have a very similar problem.

Circadian rhythms are part of the organism's organizational structure or the biological timing of this structure. Disruptions in circadian rhythms, fatigue or sleep debt can all be shown to have effects on the performance in humans. This does not mean they are all part of the same phenomenon but it does indicate that they all effect the organism's organizational structure. The manifestations that are produced by fatigue, circadian rhythms or sleep dept are very similar but are they part of the same phenomenon or are they different phenomena that are not distinguishable due to their similarity? Due to the high correlation between these phenomena it is important that a study of fatigue include some discussion of the role that circadian rhythms play in the organism's organizational structure.

Kleitman (1967) established an association of diurnal variations of human performance with body temperature. This association was so close that body

temperature was thought for some time to be a indirect measure for mental performance. In the 70's this was shown not to be the general case but that there is an additional variation according to task. Different tasks show different circadian variations in terms of phase and amplitude of rhythm. These phases and amplitudes of rhythm may also dissociate as a consequence of changes in response to shift work. (Klien, 1979, p. 1)

The list of factors that control or modify performance rhythms are:

1. If subjects are not aroused from sleep for testing but stay awake during the night, the phase of rhythm drifts towards later hours.

2. Immediate memory peaks in the morning, deteriorates through the early afternoon (1400-1500 hours) and rises again in the evening.

3. In extroverts maximum and minimum of performance efficiency came later within the circadian cycle than did introverts. (Blake, 1971)

4. Motivation may reduce circadian variation of mental performance through extra effort. Extended cycle time was found and oscillation was low for motivated individuals. When motivation was low periodicity was more pronounced.

5. When an extended duty period began at noon, the performance degradation was 10 to 15 percent. When an extended period of duty began at midnight the maximum decrement of performance was 35 percent.

6. Physical activity in the light to moderate category increases arousal. A physical load of about 30 percent of the maximum aerobic work capacity improved scores on a visual-motor coordination test in the morning and afternoon but not in the late evening and early night. The same exercise regimen impaired memory performance at all times of the day. The 30 percent physical load was too extreme for memory and

too extreme for psychomotor performance at the late evening and early night periods.

7. Increase in arousal by task-complexity and/or by higher motivation will decrease the circadian range of oscillation of performance rhythms. Reduction in arousal through loss of sleep, lack of interest, etc., will have the opposite effect. (Klien, 1979, pp. 1-3)

Figure 3 below demonstrate performance rhythms in field studies for work output, frequency of failures and number of errors. The large oscillations are explained by the interaction of fatigue caused by continuous duty and the interaction it has with the circadian depressions at night. Psychological reasons like motivation or interest may also explain the reasons for these variations.

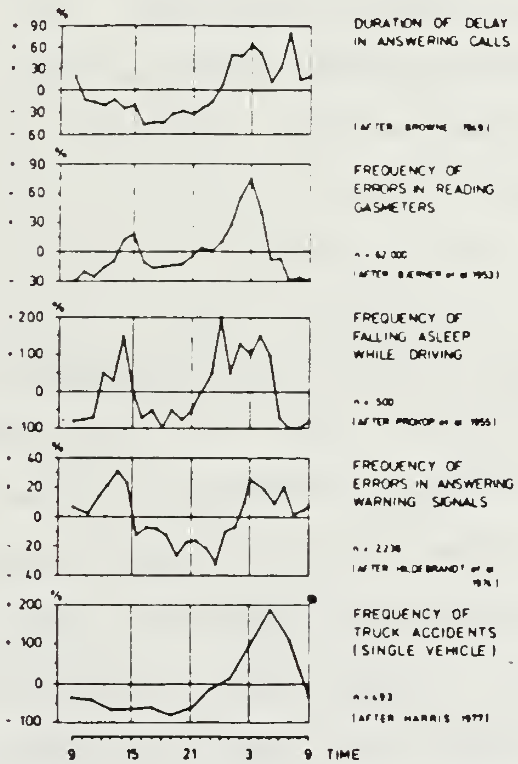


Figure 3. Performance Curves for Circadian Rhythm Patterns

Variations in the circadian rhythm are highly correlated with sleep debt and cumulative fatigue. The necessity of an evaluation technique that combines the three categories is indicated by this high correlation. How dependent are these three categories on each other? Can they be separated through controlling conditions in experiments or is controlling the conditions in experiments missing the explanation of the structure? Bartley and Chute's (1947, pp. 47-48) list of assumptions call for a method that measures the entire structure of the organism's organization. These categories are not very separable. They all deal with basically the same symptoms and compensations for those symptoms. An analysis of the spectrum of these related symptoms may give a greater insight into the amount that each plays in the make up of any one category.

D. SUMMARY

Of the studies above the most important one to this thesis is Schonpflug's (1983, p. 321) model of regulatory behavior. The eclectic assemblage of the various parts of the regulatory system has been long overdue. This model is the best at explaining the organism's organization structure and has additional insight into the relationship of fatigue to a system of demand and supply of reserve energy through stressors. This model does not explain the role of recovery, sleep debt and circadian rhythms. This workable

structure is, however, a hypothesis from which these variable elements can be put into perspective.

The difficulty which has caused the slow progress toward the definition of fatigue has been the utter complexity and variation of the elements that contribute to the phenomenon. In order to approach the complexity of the problem that fatigue represents, a number of definitions of elements that contribute to the phenomenon of fatigue had to be found. Much of this work has been accomplished but much more is still to be done.

The thrust of this thesis is on the evaluation of Schonpflug's model through the use of experimental factor analysis upon the data produced from the questionnaires. This procedure allows highly correlated data to be put into groupings that represent similar characteristics. The following chapter will, after some preliminary explanations, attempt to validate Schonpflug's model through a field survey and provide some indications of the types of questions that integrate well with the model.

III. ANALYSIS OF SURVEYS

The studies that have been conducted on the difficulties that relate to total human performance use questionnaires of mood and fatigue in order to assess the subjective status of the aircrew members. The Air Force uses the United States Air Force School of Aerospace Medicine (SAM) form 136 which consists of ten various adjectives and nouns to describe the present state of individuals. (see Appendix A). The Air force also uses SAM form 202 (see Appendix B) which assesses the subjective fatigue state and workload of an aircrew. The primary failing of these various survey instruments is that they are not including enough of the critical information necessary to assess, first fatigue and secondly performance. As was mention in Bartley and Chutes' (1947, pp. 47-49) list of assumptions fatigue is a general state of conflict of the organism's organizational structure. Many factors not just questions that are directly focused on fatigue are necessary to assess the status of an individual properly.

The difficulty in choosing the proper questions to assess a persons condition, with regard to a given state of fatigue, is extreme. Variations exist in all command units. Emphasis on performance requirements vary, training varies, environmental tasks vary, and levels of morale vary. The

use of a universal survey may not be possible and certainly not practical due to the number of variables that would go unexplained. It is therefore important to use local information in order to taylor a questionnaire to unique command requirements. In order for a questionnaire to be effective it must be based on explaining the elements of the structure of fatigue and use questions that are specific to a unique command language. The questions that make up the questionnaire need to be chosen through consideration for these unique characteristics.

With the requirements of assessing a Command's fatigue level at a given point in time, questions were chosen to take the first step in the process of designing the questionnaires. The command units that were chosen had a high probability of having experienced fatigue in the preceding months. Additional consideration was given to minimize the externalities. The commands that were chosen were operating in very similar environments and were from the same aviation community. The author has been a member of this aviation community for thirteen years. This allows first hand knowledge on the conditions that contribute to fatigue in this particular command environment.

The initial survey (see Appendix C) was designed to assess conditions of crew member's fatigue, due to command concern for safety, after a very intense period of operational flying. The following paragraphs will discuss

(a) the design of the survey and the necessary trade offs and (b) the environmental conditions that are present in both the command units that were surveyed.

A. DESIGN OF THE QUESTIONNAIRE

Operational units in the United States Military are routinely tasked with very high priority missions that require an inordinately long work week with administrative workload kept to a minimum to allow maximum resource utilization toward the operational tasks. If crew members are not flying they are standing a ready alert (which is a preparedness watch with an established minimum time to become airborne). Due to the rigors of operational commitments and desired reduction in any administrative workload, surveys must be cleared through the Chief of Naval Operations. The costs to benefits of any given survey are considered prior to approval to any questionnaire. The fatigue questionnaire that was designed for this paper had the operational costs benefits as a primary consideration during the questionnaires conception. This consideration required a quasi-experimental approach in order to accomplish an approximate measure of cumulative fatigue. This limitation was a trade off of costs versus a more exact experimental procedure for paired data samples that would call for the administration of a before test and a separate after test to the same individuals. This is the most severe limitation of the questionnaire. The possibility of a bias

sample is high with this quasi-experimental procedure, however; there are some defensible reasons beyond the necessity for minimizing costs.

The possible use of this questionnaire technique for Navy Patrol Aviation requires a quasi-experimental "one test" approach. This is due to the simple fact that any evaluation of fatigue will have to be given after the fact. One simply does not know when or if fatigue will become a factor in any given operation. If causal relationships are to be established through a technique, that technique should also fit the logistic requirements of the operations for which they are designed.

The quasi-experimental approach of this questionnaire is also necessitated by the logistical problems associated with paired samples. If two test were given the second test would require the scheduling of aircrews around the survey. It is obvious that this would not be feasible.

The possible bias of the sample is also lowered by the "safety first" training that is given to all squadron personnel. Safety is the one area of squadron that has an extensive emphasis. Realism is stressed and a serious atmosphere exists around the implementation of safety in flight operations. The airmen are not penalized for relating deficiencies in all safety related areas of operations. Fatigue is a safety related item and crew members are cautioned to observe crew rest requirements and

instructed to see the flight surgeon if they feel that their ability to fly is impaired by excess fatigue. A questionnaire is less likely to be biased by these personnel due to the knowledge of all aircrew that safety is a priority item that can save lives.

1. Questionnaire Considerations

The questionnaire's design utilizes a before and after scales of one through seven. The number one represents one extreme of the scale and the number seven the opposite extreme (refer to Appendix D). The crew member is instructed to give a "before" status followed by an "after" status. The difference represents the levels of fatigue from the thirty day period prior to the last flight.

This procedure is both biased by the inability of the person to remember his status of a month prior and possibly augmented by fact that the memory is used in the process of computing the change of the crew member's condition. The validity of this quasi-experimental one test procedure, is thus limited by the individual's recall ability. A recovery period of three to seven days was used to minimize the effect of fatigue on the subject's memory but was not so long as to allow the subject to forget the levels that existed for the period. The length of this period was chosen through the experiences of the author.

2. <u>Approach to Questions Included in Survey</u>

The first survey was designed with the regard to only the direct knowledge of conditions in the field. The conditions in the field and the additional information available though the literature was used to determine the questions that should be included in the second questionnaire. Both questionnaires had as a goal the determination of the level of degradation of performance. Therefore the second survey (Appendix D) is a mix of questions that relate to the literature on the subject of fatigue and the first survey's questions that were designed for the field only (Appendix C).

It is not a coincidence that many of the questions designed for the first survey and the ones that should be asked from the reading of the literature on the subject, are the same. A managers list of problems with regard to personnel and the effect of environmental stress on them in a field environment should be very similar to the questions involved in a laboratory test. The literature generated from many lab studies is therefore asking many of the same questions that a person faced with managing fatigued personnel must ask.

As might be expected the results of the second survey were very similar to the results of the first. With the exception of a few categories all questions were found to be statistically significant using a paired sample ttest

with a mean value of zero and alpha level of 0.05. The high correlation of the questions made the problem of separating the prominent factors from the less significant factors in a logical framework extremely complex. This was an expected result but, as investigators of prior studies have often explained in there reviews of the subject, fatigue is a very complex problem. In order to deal with this complexity and high correlation, factorial analysis with orthogonal varimax (Kaiser, 1958) rotations was needed to determine the primary factors or groupings of the questions. This approach is a unique one with regard to fatigue studies and surveys. The factorial analysis gives an objectivity to the analysis that simplifies the structure of a problem with 46 variables. The results of this analysis will be given later in this chapter. Before the analysis can be meaningful an explanation of the environmental factors surrounding the personnel that were surveyed is necessary.

3. Environment

A field environment is not as controlled as a laboratory environment but through the choice of very similar locations with similar environments the external effects upon the data can be minimized. These locations are similar but may not be typical for this aviation community as a whole.

On the whole both environments require adaptation and a large amount of adjustment. The severity of the

climate and the limited recreation opportunities places a greater than normal environmental adaptation requirement on the individual aviators.

The locations of the command units that were surveyed were Keflavik, Iceland and Adak, Alaska. These sites were chosen for their environmental similarity and because the high probability of having a large number of flight hours. The high flight time and the similar conditions lessened the possibility of bias in the sample due to variations of environment and also made the probability of significant levels of fatigue high. The descriptions of the two areas and conditions are similar enough to allow only a few differences to be pointed out during this discussion.

Keflavik, Iceland and Adak, Alaska are located in the extreme of the northern hemisphere. Keflavik is at 64 North latitude and Adak is at 52 North latitude. The climate is moderated by ocean currents that move from Southern latitudes toward the either island. Adak island is located in the Pacific Ocean and Keflavik is located in the Atlantic Ocean. The weather at both locations is very harsh during winter months. Winds are prevalent at 20-40 knots much of the year. The following list will describe both of the bases and the some characteristics of personnel.

a. Base Environment

1. Small remote bases with approximately 4000 personnel total.

2. Recreation limited

3. Accommodations are modular and dorm

4. Food services are typical for American diet

5. Tundra type terrain non perma-frost

6. Climate has varying amounts of snow and rain

7. Generally a non interactive environment during winter months.

b. Personnel in Units

1. In-door activities predominate

2. Work predominates all aspects of routine

3. Periods of time when normal sleep cycles are disturbed.

4. Periods of activity are often extremely demanding with normal flight durations of 8 to 10 hours which include an additional three or four hour preflight and a one to two hour post flight.

5. The length of the required levels of activity varies from approximately one week to continuous operations extending through months.

6. Work is interesting and varied.

7. Administrative work is minimized during flight operations.

8. Physical work is minimal and mental work predominates.

9. Crew members are above average in intelligence.

10. Fifty percent of the crew personnel are college graduates.

11. All positions require technical sophistication.

c. Differences

The primary difference between the commands is probably the management styles and performance criteria.

Many units are much the same as other units but exceptions are possible. Administrative duties may be emphasized in some units while other units may emphasize flight operations performance with a low emphasis on administrative duties. During deployments these differences should be minimized due to the operational requirements but often this is not the case. This is due to the fact that the squadron personnel have learned what to expect during periods of training. Therefore they will maintain some remnants of their performance criteria from prior periods regardless of the operational tempo. This is an unknown in these surveys. The statistical levels of significance indicate that variations of this type are not a factor. It is important to remember that the lack of a controlled environment may explain some of the variations in the factorial analysis portion.

B. DATA ANALYSIS

The analysis portion will consist of two sections. The first section will be based on the data from the initial survey from the 1985 Keflavik squadron. This first section will use the designation of "unit one" in further discussions. The second section will use the combined data from the 1987 Adak and the 1987 Keflavik squadrons. The second section will use the designation of "unit two" (the 1987 Keflavik squadron) and "unit three" (the 1987 Adak squadron) during further discussions.

1. Factor Analysis

The data analysis sections will consist primarily of graphs that simplify the interpretation of the large number of variables in the questionnaires. These graphs will represent groups of questions along similar vectors and their dimensions of change. The groupings of questions are termed "factors" and can be thought of as designator or denotation. The vertical axis represents the significance or amount of change for a given question. The factorial analysis or amount of designation is combined by the t statistics or the amount of significant change between before and after the period. This is done in order to illustrate the prominent questions for each factor. Before the graphs are presented an explanation of factor analysis and the need for its application is necessary.

Factor analysis allows an investigator that is faced with a large number of variables to find a simpler structure in a large number of possible outcomes. Due to the correlation of many of the variables or questions answered by the aircrew members it is almost an impossible task, without the aid of these computer models, to find the structure within the field of information. Factor analysis allows the investigator through various possible loadings or groupings of elements to select a model that best determines the correct outcome for the field of information. The objectivity of the process allows much of the speculative

inference to be eliminated but does not guarantee that the results are what is sought. The need for a theoretical expectation for reduction of variables is essential to this process. (Guilford, 1952) The theoretical expectation for reduction of the data into logical groupings can be illustrated by reference to Schonflug's model Figure 1.

2. <u>Choice of Method</u>

The methods of factor analysis are designed to search for new arrangements of axes within groupings of data eliminating as many dimensions, or in this case, arrangements of change between before and after, as possible. If the arrangements of change or dimensions between the before and the after period can be ascertained, then Schonflug's (1983, pp. 305-322) theorized structure should apply. If this structure is present Schonpflug's (1983, p. 321) model can be validated and prominent features discovered. The purpose of this analysis is to simplify and characterize fatigue by giving greater definition to this theorized underlying structure.

a. Varimax Rotation

The focus of factor analysis is on some set of imaginary scores from which the observed scores are derived. Factor analysis is much like a reverse multiple regression problem, where the results of the analysis are known and what is sought is the scores that give the result. (Amick and Walberg, 1975) In the case of this survey it can be

assumed that the fatigue level is the result and the questions in the survey are the factors that may or may not explain fatigue. These questions if important to an explanation of fatigue should be included in a hypothetical regression equation and if they do not explain fatigue should be left out.

A non rotated or simple factor analysis loaded heavily on the first factor, fatigue, and did not solve the structural problem that was proposed. This necessitated that a rotation be introduced into the factor analysis in order to find the simple structure. Varimax rotation was the best for determining simple structure. The robustness of the solution was generally very good. This was determined by using various types of rotation (Harris, 1967) and comparing their results. These results were very similar, with Varimax giving the most interpretable results. The factors were also plotted in order to determine if further rotation was necessary. The results of these plots showed a very good grouping of data along the axis with no large number of outlying points.

3. <u>Results</u>

The definition of the results of this simple structure produced by using the Varimax rotation or any other factor analysis computer program is subjective. (Amick and Walberg, 1975, pp. 168) The theory and assumption that an underlying framework for fatigue exist is based primarily

on the work of Bartley and Chute (1947, pp. 47) but has been called for and sought after by many others through the preceding and following years. The primary reason for the use of factor analysis is to improve the objectivity of the approach to the problem.

C. UNIT ONE

The squadron was deployed to Keflavik Iceland in the spring of 1985. The operations from which the this initial survey a rose were very demanding. The crews that were given the survey had flown approximately 120-150 flight (approximately 70 hours more than unit 2 and unit 3) hours during the prior month. This is significant because the maximum flight hours advised by the Air Force and Navy manuals for a two piloted aircraft is 120-125 hours.

This initial survey (Appendix C) was conceived primarily from observations made during the period and from managerial considerations with regard to discerning the information that might aid others under similar circumstances.

1. The Results of Unit One Data

The result of the Varimax rotation on unit one data is combined with the t statistic for each question in the following Figures 4-11. The bottom scale or X axis represents the dimension of the loadings of various questions, on a scale from zero to one. A score of one represents very strong loading of the question on the factor. The score of zero would represent no loading on a

factor. The cutoff chosen for the loading was 0.37. Due to the 0.37 cutoff the X-axis starts at 0.3 and has a maximum value of one.

The t statistic was chosen to represent the statistical significance of the question. The t statistic was computed by using a paired sample statistical t-test of the before and after values from the survey questions. The t statistic gives the best overall indication of the level of certainty that can be assigned to the level of statistical significance of the difference between the before and after values of the questions. The level of 0.05 significance for a two tailed test is chosen as a null hypothesis test criteria. With a sample size of 30 for the survey a minimum t value of approximately 2.0 and above is statistically significant. The P values of 0.05 and lower were present if the t statistic was greater than 2.0. A scale from 0 to 10 was chosen on the graphs in order to include all values of the t statistic for various questions.

2. <u>Comparison</u>

The t statistic and the loading factors do not lend themselves to a one to one comparison. The combination of the two do, however; allow simplifications of computations required to determine weather a question is significant enough to be included in a factor or group. It is important to combine the independent scales in order to eliminate non significant questions. The further the data point is away

form the X and Y axis the more significant the question is in determining the group or factor as a whole. The objective is to find the most important and explanatory question for a given factor or group. The factor loading or X axis is the explanatory or designation scale for the factor and the Y axis or t statistic is the amount of change or statistical significance of change that a question has. The X axis explains the designation of the factor and the Y axis gives levels of change in statistical terms. The t statistic was chosen as a measure of the Y axis because it allows for the standard error as well difference between the mean value as compared to zero or no change in the paired sample t test.

The figures below represent factors one through eight for unit one. An explanation will precede each graph. The questions that are present in each factor are presented at the right of the graph in a shortened form. If the reader desires the complete question please refer to Appendix C.

3. Factor One

The maintenance of efforts for long extended periods seems to have an effect on the internal reserve resources of the individuals. "Exhaustion of internal resources will show up in difficulties of maintaining or raising effort." (Schonpflug, 1983, p. 317) This lack of internal reserve resources requires that individuals also rely on strategies

that require more use of external resources. This use of external resources is illustrated for factor one by: "Crew interaction?", "How much fatigue did you observe in others?", "Tolerance level?" and "Conflicts?". Due to the high levels of significance and the relatively high loading of "Tolerance level?" and "Crew interaction?" external use of resources had been carried to a very high level for unit one. The use of external resources may be a good indicator that safety margins are getting strained. If crew interaction and tolerance are low, with a given condition of change in competence great enough to require more use of external resources, then the lack of or difficulty in ascertaining this external aid may cause a critical task be delayed or go unnoticed. The fact that this may be occurring may be a good indirect indicator that the competence levels of individuals are being tested and margins of safety are lessened by the human factor.

Schonpflug's model of regulatory behavior Figure 1 can be integrated very well with this factor. Using the t statistic as an indicator of prominence of each question the following Table 1 will represent the question and the part of model that it represents. Table 1 represents the significant change of the paired sample t test It is very apparent that this factor contains many of the parts of the Schonpflug's model. The interpretation of this grouping is:

TABLE 1

FACTOR ONE

The questions will be listed in order of significance from top to bottom.

	Question	Model placement
1.	Fatigue others	Fatigue
2.	Tolerance level	Internal demands
3.	Alertness	Internal demands to Aspiration
4.	Conflicts	Problems to feeding back into regulatory system
5.	Power Curve	Competence to coping
6.	Sense of humor	Coping
7.	Crew interactions	External to model or coping
8.	Vision	Competence
9.	Endurance	Internal demands to activation
10.	Ability on job	Competence

a. This group explains 4.994 of the 29.837 over all variance, in other words this factor is most significant in explaining the designation variation in the questionnaire.

b. This ordering of questions can be interpreted through the model as Internal demands having the largest decrement, competence to coping having the second largest decrement, and as stated above external reliance is having influence on the regulatory system.

Figure 4 below will allow the reader to visualize the groupings of questions in this factor with regard to

designation or factor loading on the X axis and dimension of significant change or t statistic on the Y axis. All questions in this grouping are important in explaining the changes in aspiration level, activation effort, competence, coping and exhaustion of internal resources.

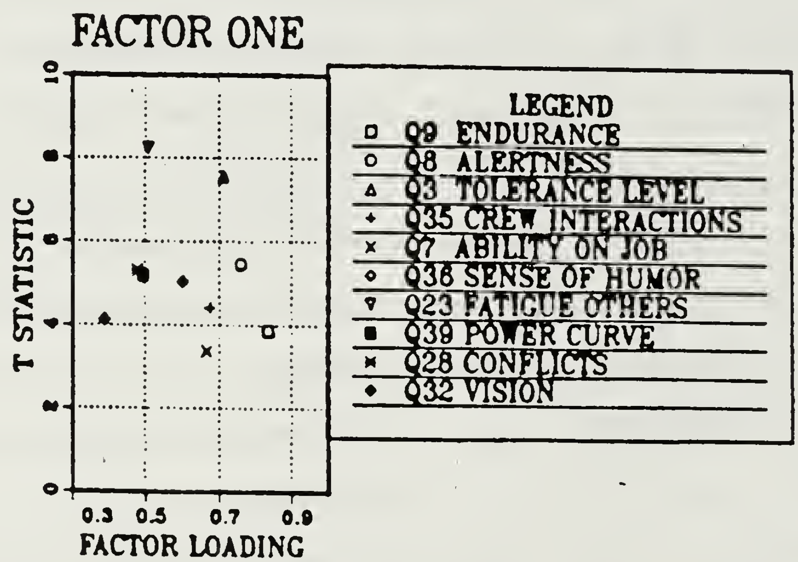


Figure 4. Factor One

4. <u>Factor Two</u>

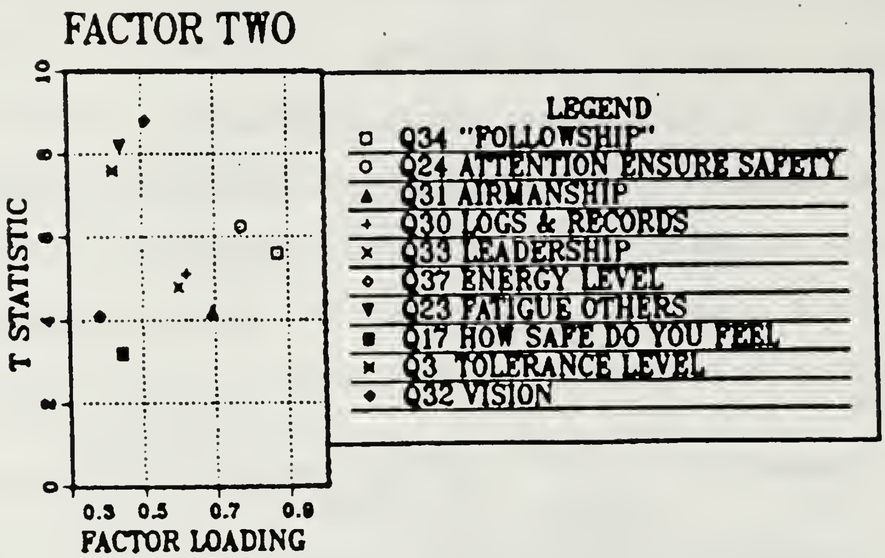
Factor two and factor one are very similar with regard to Schonpflug's model. Table 2 for factor two has many of the same parts of the regulatory model that factor one's had. This table demonstrates that the same parts of the model that were present in factor one are present in factor two. The difference is in the area of coping.

TABLE 2

FACTOR TWO

	Question	Model placement
1.	Energy level	Internal demand to activation
2.	Fatigue others	Internal demand
3.	Tolerance level	Coping to internal demands
4.	Attention to ensure safety	Activation effort to coping
5.	"Followship"	External demands through system to problem
6.	Logs and Records	Aspiration to activation effort to coping to problem
7.	Leadership	Internal demands to competence to coping with problem
8.	Airmanship	Competence to coping
9.	Vision	Competence
10.	How safe did you feel	Coping to problem

Factor two has many of the questions centered around coping. Figure 5 below adds the designation or factor loading dimension to the table above. The observation that can be drawn from Figure 5 is that this factor deals primarily with questions that relate to coping and problem resolutions. Which is the goal of the model's structure. Please refer to the list of questions in Figure 5's legend which are in the order of prominence of factor loading. It seems that factor two and factor one both deal with coping and problem



This figure will be summarized as changes in coping and problem resolution.

Figure 5. Factor Two

resolution. At this point an excerpt from Schonpflug (1983, p. 304) will explain this observation.

> Ineffective coping attempts form a major source of stress. They combine the costs of control with the costs of continued problem orientation. While they are continued, concern is directed towards the person involved, his arousal, his worries, his uncertainty of proceeding, his cognitive and behavioral disorganization. These are states which most probably will deviate from a person's internal demands. And, therefore, the concern for primary emphasis of inefficiency may well be augmented by increased self-concern. This self concern, combined with heightened arousal, may add a substantial component of emotional load to the existing amount of stress. If concern for internal states is finally not effective in regulating these states and does not restore the efficiency of coping with the primary problem source, a vicious circle may result. Inefficiency increases stress, and stress increases inefficiency. Coping attempts, while being effective or ineffective in solving old problems, may generate new ones.

This quote explains the relationship of coping to problem resolution and the residual that can result. There may also be a close link between stress and fatigue. In this factor one can assume that there is a possibility that the vicious circle caused by not restoring efficiency in coping may be occurring.

5. Factor Three

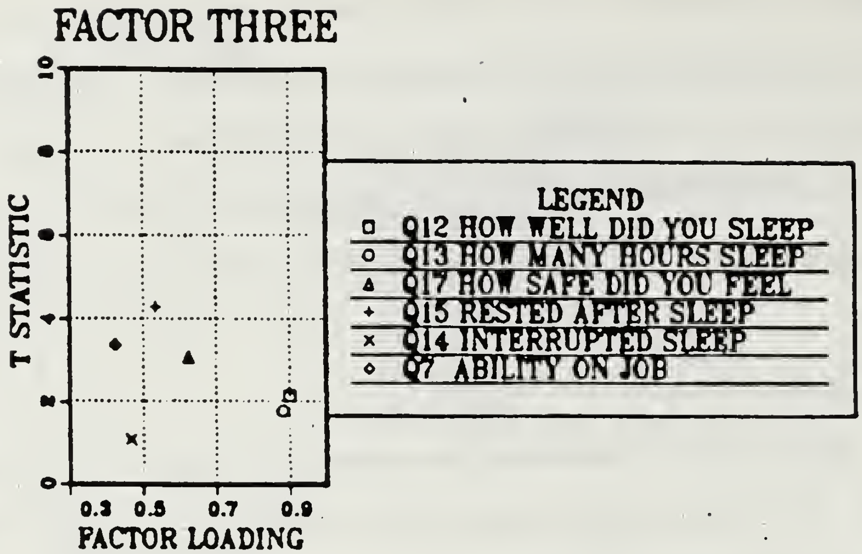
This factor represents sleep. Table 3 will list the parts of the regulatory behavioral model and the questions that relate to these parts.

TABLE 3

FACTOR THREE

Question	Model placement
1. Rested after sleep	Fatigue to internal demands
2. Ability on job	Competence
3. How safe did you feel	Coping to internal demands
4. How well did you sleep	Fatigue to internal demands
5. How many hours sleep	Fatigue to internal demands
6. Interrupted sleep	Not significant enough to include

These levels of significant change must be coupled with the factor loading or designation in order to correctly interpret this factor. Figure 6 below allows an overall interpretation of the questions in this factor and the



This figure represents sleep.

Figure 6. Factor Three

significant levels of change in each question to be compared. The interpretation is that fatigue recovery through sleep is related to the "coping to internal demands" and to the "competence" parts of the model. This association is important to the explanation of sleep's role in a system of regulatory behavior. If sleep is linked to coping and competence it is linked to problem resolution also.

This factor represents 3.789 of a total 29.837 commonality for all eight factors. The 3.789 value is well above an established significance value of one that is standard for factor analysis. These levels indicate that sleep is important to the regulatory behavioral system and

sleep effects change in coping, competence and ultimately problem resolution.

6. Factor Four

The fourth factor is related to external reliance. This factor will be called external reliance outside of the crew. Table 4 represents this factor's relationship to the behavioral regulatory model as determined by significant change determined by a paired sample ttest.

TABLE 4

FACTOR FOUR

Question	Model placement
1. Power Curve	Coping to problem
2. Sense of humor	Coping
3. Vision	Competence
4. Need to assist others	External demand to problem
5. Brief/Debrief length	External demand to problem
6. Support of facility	External demand to problem

It is necessary to refer to Figure 7 in order to get the correct interpretation of this factor. Although Q19, Q10, and Q18 are not statistically significant they do represent this factor. This factor can be designated as external reliance because the level of significance and the designation of a factor are independent of each other. It

is not surprising that coping and competence also change with external demand.

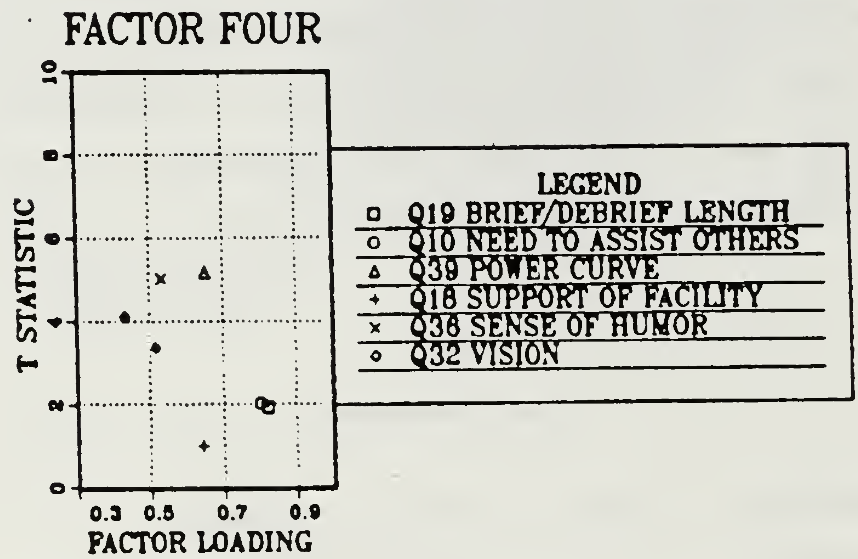


Figure 7. Factor Four

a. Factor Five

The fifth factor is a repeat of the problem resolution or competence decrease brought on by fatigue. The question "Conflicts?" (Q28) indicates that conflicts may have been caused by lower internal reserves of individuals and the external reliance on other crew members. When this occurred greater crew efforts were required to compensate for lowered internal reserves of energy in each individual. The conflicts a rose out of the tradeoffs each crew member had to make for a total crew effort.

Table 5 is based on the same parameters as mentioned before. It is a list of significant questions and the parts of the behavioral model they represent.

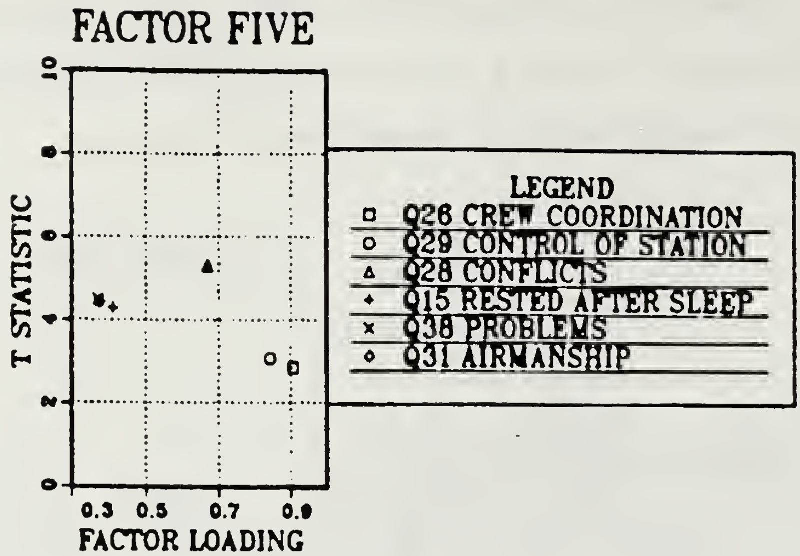
TABLE 5

FACTOR FIVE

Question	Model placement
1. Conflicts	ExternaL demand to problem through system and possibly into loop of non problem resolution
2. Problems	Coping to problem, possibly into loop of problem orientation but non resolution
3. Airmanship	Competence to coping
4. Rested after sleep	Fatigue to internal demands
5. Control of Station	Competence to coping
6. Crew coordination	External demand through loop to external reliance

Figure 8 is the best reference for the interpretation of this factor. External and internal competence seem to be the primary designation for this factor and this is contrasted with problem resolution, coping and indications that the non resolution of problems was feeding back through the system. This situation can be explained through a Quote form Schonpflug (1983, p. 305).

> Coping attempts, while being effective or ineffective in solving old problems, may generate new ones. Problem generation can be regarded as another way of increasing



Factor five represents the non resolution of problems and disorganization due to demand exceeding capacity in the individual.

Figure 8. Factor Five

> costs. The creation of self-related problems due to inefficient handling of a primary task is just one kind of problem generation. A driver in an ambulance drives quickly in order to save a patient with a heart failure and hits a passenger in the street. In this case a new problem arises while an old problem remains unsolved.

This anecdote gives a simple example of non resolution of problems due to demand exceeding capacity. This factor is important in as much as it gives more validation to the hypothesis that the behavioral regulatory model has a feed back loop in which non problem resolution is a prominent cause of disorientation and this non resolution causes degraded performance by the individual.

b. Factor Six

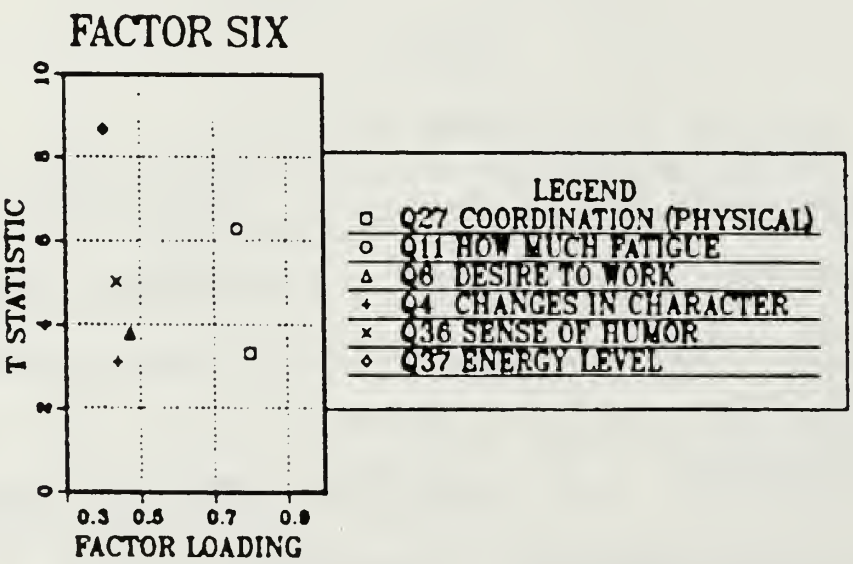
Factor six is characterized by what is normally called fatigue. The indications from this factor is that subjective fatigue is very high (question: How much fatigue Q11) and that the perceived levels were high enough to inhibit clear and precise action (question: Personal coordination abilities Q27). All other factors loaded comparatively lower and describe tactics of coping with these fatigue levels (question: Desire to do less work Q6, Changes in character Q4, Sense of humor Q36). Table 6 represents the questions as they relate to the significant change in the paired sample ttest.

TABLE 6

FACTOR SIX

Question	Model placement
1. Energy level	Fatigue to internal demand
2. How much fatigue	Fatigue to internal demand
3. Sense of humor	Coping
4. Desire to work	Internal demand to aspiration level to activation effort
5. Coordination (physical)	Competence to coping
6. Changes in character	Internal demand to activation to learning to competence to coping

Table 6 and Figure 9 indicate that fatigue is prominent as stated above. Various strategies are used to deal with fatigue within the model. There seems to be a drop in aspiration and activation as well as coping strategies and learning. Two basic changes are indicated. One a lowering of energy expenditure and an increase or change in the normal way of coping. Both of these basic avenues of reduction of effort and change in orientation toward coping and problems are predicted by Schonpflug (1983, pp. 303-320). The indication is that change and reduction are occurring.



Factor six describes levels of fatigue.

Figure 9. Factor Six

7. Factor Seven

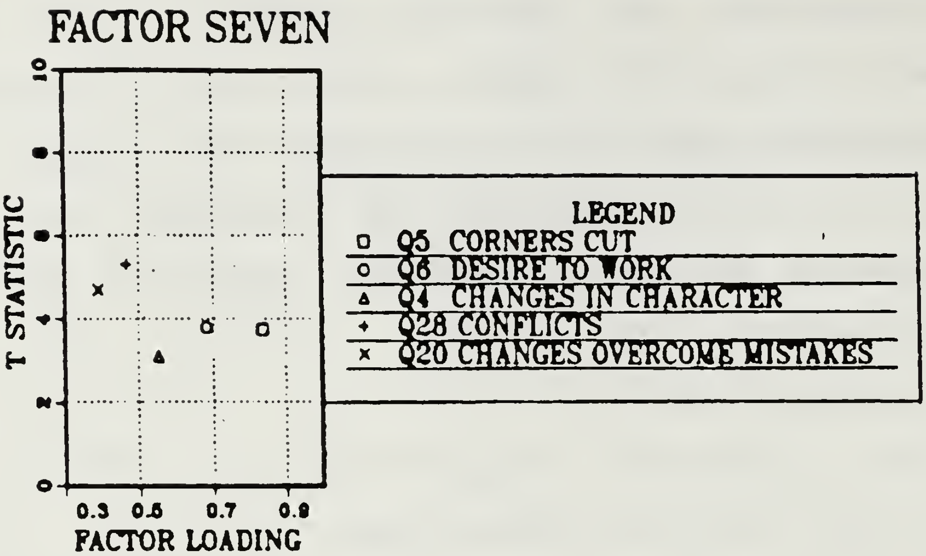
"Corners cut" will be the name of this factor. "Corners cut" can be interpreted not as poor job performance but as better strategies of coping with fatigue levels. Table 7 is used to integrate the regulatory model to the questions in order of significant change for the paired sample ttest.

TABLE 7

FACTOR SEVEN

Question	Model placement
1. Conflicts	External demand to problem through system and possibly into loop of non problem resolution
2. Changes to overcome	Internal demands to activation to mistakes learning to competence to coping to problems
3. Desire to work	Internal demand to aspiration level to activation effort
4. Corners cut	Aspiration level to activation to coping
5. Changes in character	Internal demand to activation to learning to competence to coping

The designation of this factor as corners cut also agrees with the interpretation of the regulatory model. With reference to Table 7 and Figure 10, the best



This factor represents strategies for coping with fatigue and the inefficiencies that may have occurred due to cut corners.

Figure 10. Factor Seven

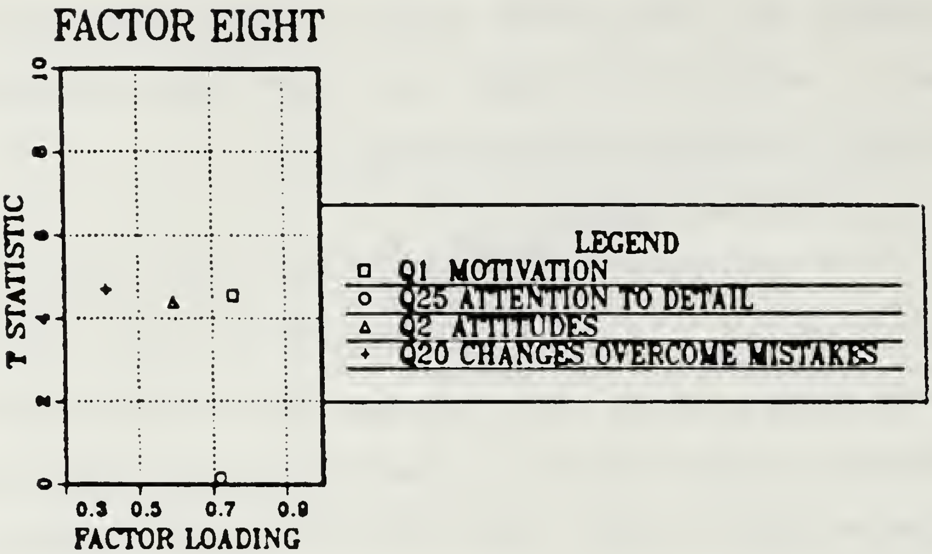
designation is from the figure's factor loading data. The interpretation of the other questions can be centered around "coping" within the model. All of the questions deal with strategies or changes that are made in order to cope. This factor indicates that there was an overall attempt to cope with problems through reduction in aspiration level. The indication is that demands were exceeding supply of internal reserves and that reduction in expenditure of resources was necessary. The question Q20 "Changes to overcome mistakes?" indicates that there was also non resolution of some problems. This same question indicates that learning was

taking place. The end result is not an ideal aviation environment but the safety record during this period was perfect. Margins of safety may have been effected but observable safety results were not.

a. Factor Eight

The very high loading and the fairly high t statistic gives a very good indication that this factor represents motivation. The literature on fatigue is full of references to this factor in assessing or measuring fatigue. It appears that in this case motivation was degraded at or near the same level as most of the other questions except for "Attention to detail?" The question "Attention to detail?" is not significant due to an ambiguity of possible interpretations by the subjects that took the questionnaire. This requires that it be removed from the discussion.

All three questions useful questions can be associated with the "Aspiration level to Activation effort to Coping" part of the regulatory model. These three questions represented in Figure 11 have very similar levels of significant change. The interpretation that can be given through the use of the model is that motivation is involved in aspiration levels, activation and coping. The end result may be a form of compensator which attempts to overcome mistakes. This takes the form of focused effort to overcome problems caused by the lower aspiration of the preceding factor.



This factor represents the first question listed Q1 motivation.

Figure 11. Factor Eight

b. Factor Nine

This factor represents the awareness of fatigue as a contributor to regulatory behavior of the individuals surveyed. An increased t statistic of 3.73 and a factor loading of 0.878 was present for the question 22 "How aware of fatigue were you?" These values indicate that the computational strategies of the personnel surveyed did include fatigue as a factor in there performance.

8. Communality Estimates

The final communality estimates total 29.837 The loading for each factor in explaining the communality total are given in Table 8.

TABLE 8

LOADING OF FACTORS

Factors	Variance explained by each factor (Any number over one is considered significant)
Factor 1	4.994
Factor 2	4.495
Factor 3	3.798
Factor 4	3.238
Factor 5	3.235
Factor 6	2.774
Factor 7	2.760
Factor 8	2.431
Factor 9	2.114

9. Summary

The first two factors indicate that the situation for unit one was extreme but not overwhelming. The best indicator for this extreme condition is that internal resources are depleted to the point that some over reliance on external resources may have occurred. This was evidenced

by the questions Q28 Conflict, Q3 Tolerance level and Q35 Crew interactions that loaded on the first factor. Many of the following factors repeated this basic phenomena.

Sleep was related to the regulatory behavior model. The mean value for sleep was 6.5 hours for the group which is at least adequate for a normal sleep cycle. Sleep debt is probably not a contributor to the changes that occurred over the month. The recovery that sleep accomplished was related to competence and coping. This indicates that sleep does effect change in competence and coping. The indications are that sleep is an external part of Schonpflug's and that it does effect change in competence and coping of individuals.

All of the factors for unit one demonstrated a large amount of interaction of parts of the model. Not all of the parts were present in any one factor but all of the parts of the model were present in at least one of the nine factors. Schonpflug's model integrates extremely well with all of the factors and contributes greatly to the explanations of the phenomena they represent. The second questionnaire will give another opportunity to test this model. The level of fatigue is different for units two and three but the model should still explain the factors as clearly as they did for unit one.

D. RESULTS FOR UNIT TWO (KEFLAVIK) AND UNIT THREE (ADAK)

The following factors are the result of the combination of the 1987 Keflavik and 1987 Adak squadron data. The differences between the two were so small that the combination of the data serves to, one, improve the degrees of freedom for the factor analysis and the paired sample ttest and, two, to decrease the complexity of the overall analysis.

The increase of the data base to a total of 70 rows of data improved the robustness of the solutions presented by the factor analysis. Unit two and three data were run separately and the results for the factor analysis and the paired sample ttests were very similar. The same groups of questions loaded on the various factors, with only a slight change in the ordering of the factor sequence. The overall average flight time from a combination of both squadrons for the 30 day period is 51 flight hours. Unit two averaged slightly higher at 61 hours and unit three slightly lower at 45 flight hours.

The combination of the data served, due to the similarity of conditions, to improve the overall results of the analysis for the paired sample ttest. The greater number of data samples increased the t statistic for the analysis graphs for unit two and three. The larger sample size should be kept in mind if comparisons are made between the combined data sample of 70 for unit two and three and

the smaller sample of 30 for unit one. Relationships within the graphs are the primary emphasis for this analysis and any comparisons with unit one will consider the relative difference of the sample size.

1. Factor Loading and T Statistics for Units Two and Three

The procedure of explanation used for the preceding graphs will be used for the graphs that follow. The analysis will precede the figures and the questions, in the order of loading prominence, will be presented to the right of each graph.

2. Factor One

The questions "Alertness?", "Ability on job?", "Endurance?", and "Vision?" are the same for unit one and the combined unit two and three factor one. Missing from unit two and three's factor one are the questions that indicate reliance on external resources. The questions that indicate reliance on external resources are dispersed throughout unit two and three factors. This is consistent with the assumption that reliance on external resources may be a good indication that limits of ability are being reached. Unit one had approximately 130 hours flight time for the month preceding the test. Unit two and three had approximately 51 hours flight time. This indicates that the use of external resources which are assessed through questions like tolerance level, crew interactions, fatigue others, and conflicts are present at high levels of flight

time and not at more normal levels like of approximately 50 hours.

Maximum mobilization of attention is also indicated as the primary emphasis for factor one for unit two and three. As was mentioned in the results from "Psychometrics of Fatigue," tasks that require a maximum mobilization of attention are the best indicators for fatigue.(Zinchenko, 1977, pp. 72-73) Factor one indicates that alertness as well as attention to detail represent this prominent factor and also have very high t statistics. The question alertness also loaded heavily on factor one of unit one with a relatively high t statistic. The conclusion can then be drawn that questions like alertness and attention to detail are good indicators for assessing fatigue.

The classic symptoms of fatigue are also present in this factor. Endurance, logs and records, vision and energy level all appeared in this grouping. These are what Bartley and Chute (1947, pp. 52-56) referred to in a section of their definition of fatigue. "Fatigue is part of an individuals stance toward activity, attitude, maintenance of posture, or the simple need to stay awake." (Bartley and Chute, 1947, p. 54)

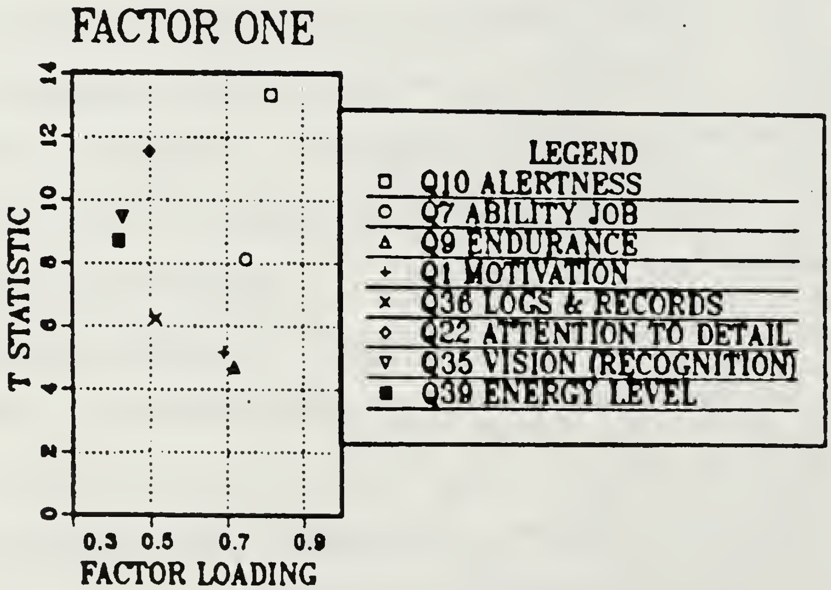
Table 9 below represents how factor one is integrated into the regulatory model.

The combination of Figure 12 and Table 9 indicates that this factor does not indicate high external reliance.

TABLE 9

FACTOR ONE

Question	Model placement
1. Alertness	Activation effort
2. Attention to detail	Activation effort to coping
3. Vision (recognition)	Learning to Competence
4. Energy level	Fatigue to internal demands
5. Ability on job	Competence to coping
6. Logs and records	Aspiration to activation to coping
7. Motivation	Aspiration to activation to coping
8. Endurance	Fatigue to internal demand



This figure represents the difficulty in the mobilization of attention as fatigue levels become greater.

Figure 12. Factor One

This data can be interpreted more in terms of the internal workings of the behavioral model. Activation effort is central to this factor. With fatigue effecting internal demands and internal demands effecting the rest of the model. Coping does not seem to be prominent but a result of the workings of the rest of the system. This indicates again that the regulatory system is not having difficulty with non resolution of problems.

Figure 12 is an overall representation of the factor loading and the t statistics for each question.

3. Factor Two

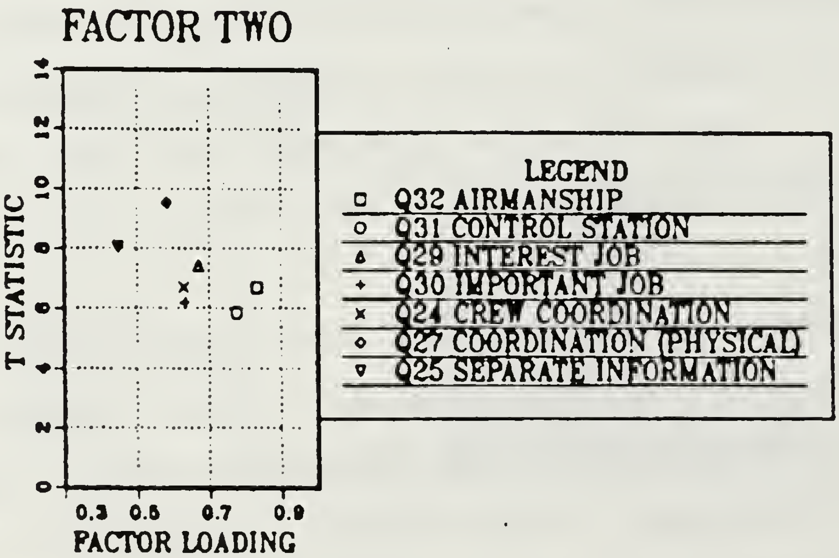
Factor two has a primary emphasis on performance of duties pertaining to the crew member's job. The entire list of questions can be directly associated with a crew member's mental involvement and control of actions relating to work activity. This indicates that unit two and three were experiencing degraded interest and control over job related functions.

Table 10 represents the integration of the regulatory model and the questions. Table 10 and Figure 13 allow an interpretation of the regulatory model. Competence seems to be central to this factor. Fatigue and internal demand do not seem to be influencing the competence of the individual but interest and importance of the job does. At these levels of flight hours the external reliance and non resolution of problems does not seem to be present.

TABLE 10

FACTOR TWO

Question	Model placement
1. Coordination (physical)	Competence to coping
2. The ability to separate	Competence to coping to problem information
3. Interest in job	Aspiration to activation
4. Airmanship	Competence to coping
5. Crew coordination	External demand through loop to external reliance
6. Importance of job	Aspiration to activation
7. Control of station	Competence to coping



This figure represents competence as it relates to work activity.

Figure 13. Factor Two

Competence does seem to effected to some degree. This factor does seem to remain within the confines of the regulatory model. Competence seems to be related to work activity in this factor.

4. Factor Three

All the questions that loaded on factor three were related to communications and integration with the exception of the question that dealt with interrupted sleep. The interrupted sleep question was not statistically significant and loaded the lowest for this factor it will be eliminated from the explanation for this reason. The questions that dealt with crew interaction, efficiency of others, coordination of others and ability to cope with a lot of information at one time all deal with communication and control within the crew.

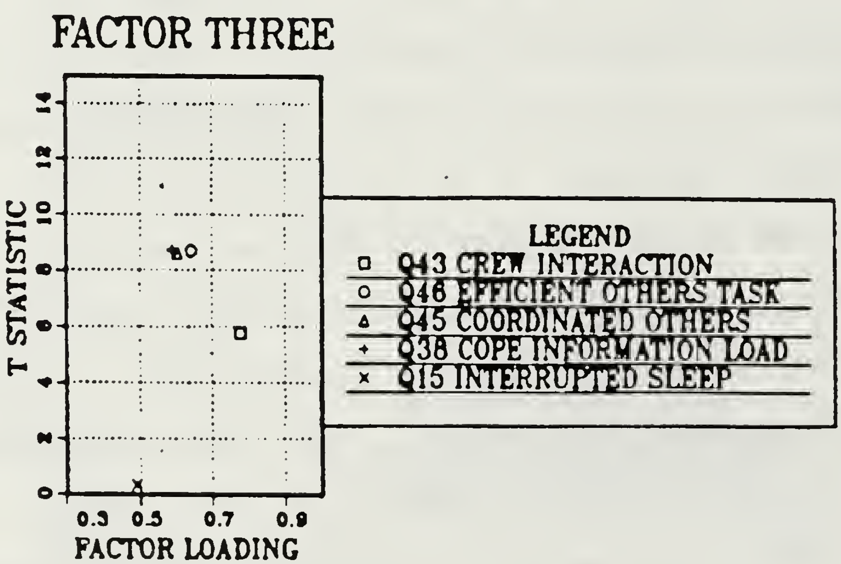
Table 11 and Figure 14 will be used to integrate Schonpflug's (1983, p. 321) model with this factor.

Crew interaction was the question that is primary in the designation of this factor. The other three questions seem to be the primary subsets of the highest loading question "crew interaction?" As stated earlier communications and control are almost synonymous with "crew interaction." The model can then be analyzed for the effect of communication and control in the model, at this level of fatigue. Apparently the modes of internal demand, activation, coping and problems are all effected at this

TABLE 11

FACTOR THREE

Question	Model placement
1. Cope with information	Coping to problems load
2. How efficient were	Internal demand to activation others in performing task
3. Coordinated others	Coping
4. Crew interaction	External through system



This figure represents degradation in communications and control between crew members.

Figure 14. Factor Three

level of fatigue. Apparently the modes of internal demand, activation, coping and problems are all effected at this

level of fatigue. It is important to point out that this is very likely a slightly below normal condition. Absent from this list are conflicts, tolerance, and lowered aspiration level type questions. Communication and control is effected but not to an extreme degree. There is no indication that non resolution of problems is taking place in this factor.

Figure 14 represents the crew interactions of units two and three.

a. Factor Four

The interpretation of factor four requires some use of the authors experience in these squadrons operating environments. The high loading and high t statistic for the question regarding balanced diet indicates that this category represents disruption of routine and is not directly associated with diet. This question is important but must be considered in concert with the other questions grouped in this factor. A disrupted routine causes logistical problems for crew members. Schedules are almost entirely dictated by the operational environment surrounding the squadron. The normal routine is kept by support personnel but crew members are on an operational routine that is really not a routine at all. The end result of the routine disruption is the aviators meal which consisting of various forms of "junk" food and soft drinks. This first hand knowledge of conditions leads the author to conclude

that circadian rhythms may be part of this factor. Three sleep questions were included in the grouping as well as tolerance and balanced diet. A tenuous conclusion can be made that this factor represents circadian rhythms effects as well as diet. If this factor does represent circadian rhythms disruption then the best question to assess the impact is how rested did you feel after sleep. Degradation in balanced diet would be in most cases the norm and would not indicate much more than disruption of routine with regard to circadian rhythms.

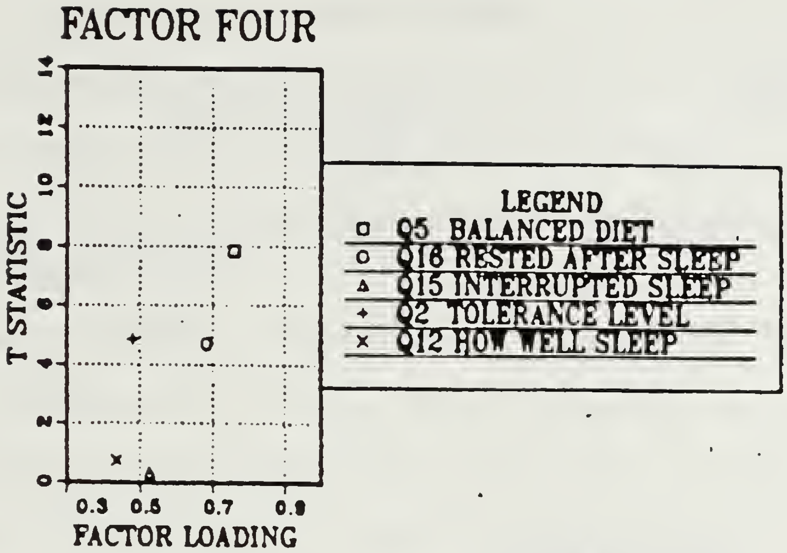
Table 12 and Figure 15 will be used to interpret the regulatory model and its relationship to this factor.

TABLE 12

FACTOR FOUR

Question	Model placement
1. Balanced Diet	External to model
2. Tolerance level	Coping
3. How rested after sleep	Internal demand/recovery
4. How well did you sleep	Internal demand/recovery
5. Interrupted during sleep	Internal demand/recovery

The tenuous conclusion that this factor deals with circadian rhythms is the best way to explain "Balanced diet?" as the highest loading question in this factor. The model analysis can only add that coping and internal



This figure can best be generally described as a disruption in routine.

Figure 15. Factor Four

"demand/recovery" is present. The model still leaves this tenuous conclusion tenuous. Disruption of routine seems to be a less abstract explanation.

Figure 15 represents the disruption to routine in an operational environment.

5. <u>Factor Five</u>

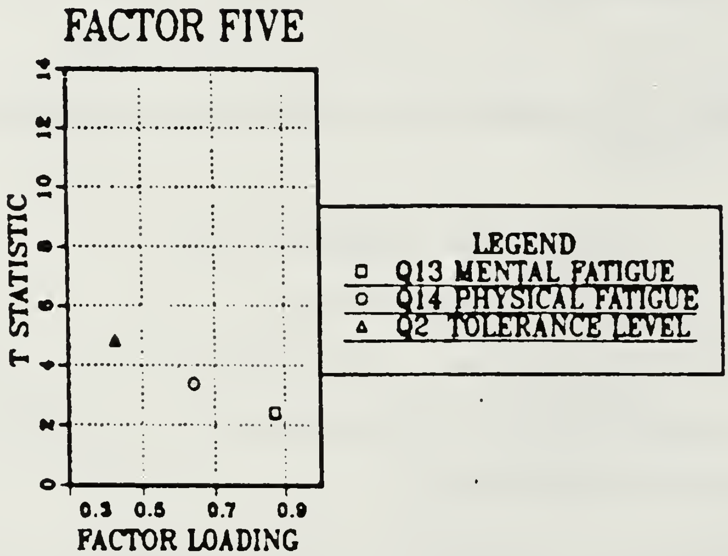
This factor can be classified as cumulative fatigue. Both questions that relate directly to fatigue were present. The question tolerance also was significant in the factor.

Table 13 and Figure 16 will be used to interpret the regulatory model and its relationship to this factor.

TABLE 13

FACTOR FIVE

Question	Model placement
1. Tolerance level	Coping
2. Cumulative Physical fatigue	Fatigue to internal demand
3. Cumulative Mental fatigue	Fatigue to internal demand



This factor represents cumulative fatigue.

Figure 16. Factor Five

The model's addition to the analysis is that coping is linked to fatigue and internal demand. This is probably accomplished through activation effort which can allow one

to conclude that tolerance level represents a lower desire to be active and that the arrow in the model may need to point toward and from coping with regard to the lines coming from internal demands and activation effort.

Figure 16 represents cumulative fatigue.

6. Factor Six

Factor six is directly related to compensators. These compensators were first referred to during lab experiments by McFarland (1932, pp. 1-35). The compensation to ensure that task are completed should not to be taken as a negative indication. These compensations are in some cases strategies to lessen work load, increased emphasis on critical areas, or simply working harder to overcome the fatigue that is being experienced. These compensators are indications that extra internal resources are being used to overcome existing conditions. If these levels are very high then there may be an unsafe condition developing but a level of this indication would be very difficult to establish.

Attention to detail did not load heavily on factor six but has a very high t statistic. This indicates that compensation for the fatigue experienced due to mental information loads is much higher for detail than for ensuring performance or overcoming mistakes. The fact that all three compensator questions loaded on this factor indicates that they are the same basic phenomenon. One of these questions without the others would not assess this

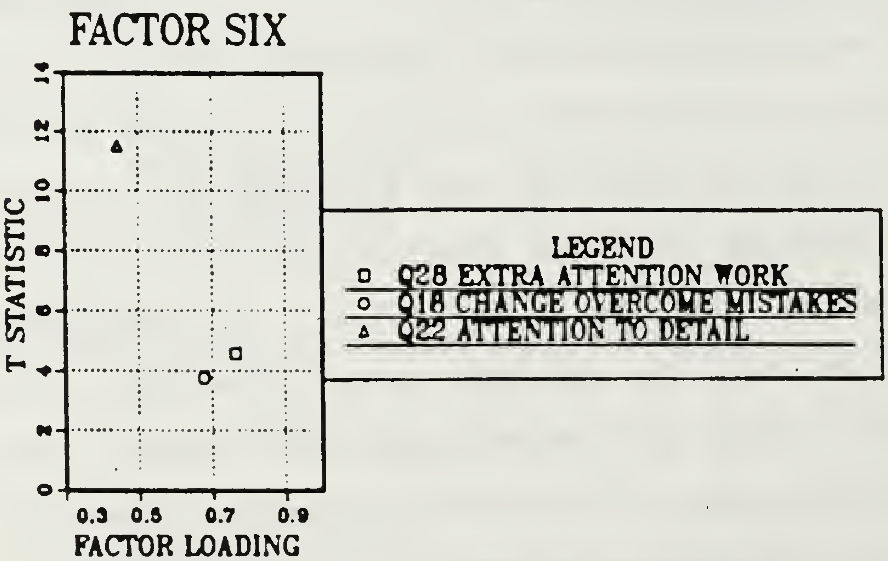
factor as clearly. Even more specific questions might improve the interpretation of fatigue.

Table 14 and Figure 17 will be used to interpret the regulatory model and its relationship to this factor.

TABLE 14

FACTOR SIX

Question	Model placement
1. Attention to detail	Aspiration level to activation
2. Extra attention to ensure performance	Aspiration level to activation
3. Changes to overcome mistakes	Activation to learning to competence to coping to problem



This figure represents compensation for a fatigue condition.

Figure 17. Factor Six

The model interpretation adds little to the analysis above. Aspiration, activation and a feed back loop is indicated by the question "Changes to overcome mistakes?" All levels were significant but attention to detail is the most affected. This may indicate that as attention to detail drops the compensations for errors take place. Schonpflug's (1983, p. 304) vicious circle of problem non resolution may be indicated by these three questions.

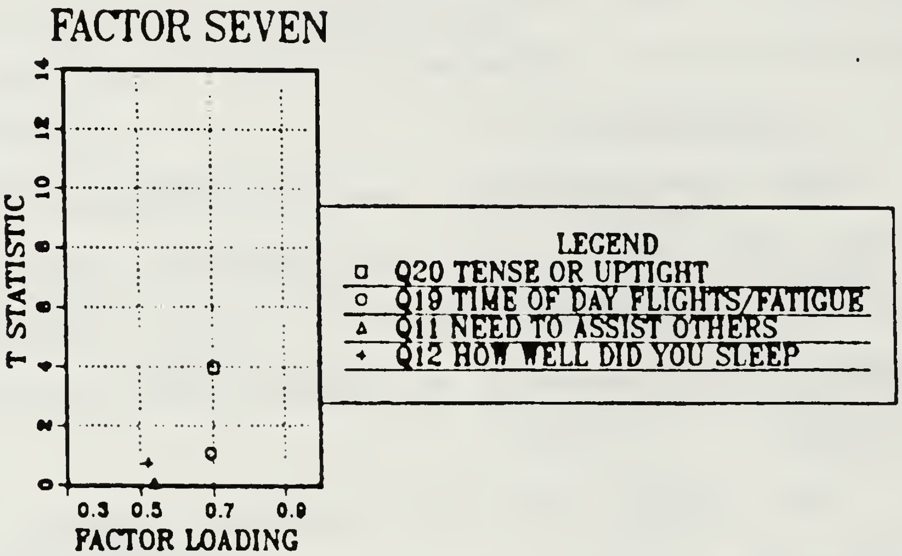
7. Factor Seven

For this and the remaining factors the first question that loads will be considered the name that summarizes the factor. Due to a single question factor loading no model analysis for factors will be given until the summary.

For factor seven the question tense or uptight summarizes the factor. The remaining questions represent subsets of stressors that are contributing to the first the tenseness of the crew member. The tenseness is effecting the quality of sleep of the crew member. The anticipation of an instant start up of an evolution during ready alert status is represented by the question flight time of day. The requirements of crew evolutions are becoming more demanding and less easy to tolerate is represented by need to assist others. The assessment of this factor is best represented by question 20 Tense or uptight. This is due to the very low t statistics for all the questions except for

tense or uptight. This may be due to the grouping of minor stressors, which would not be significant in themselves, into a overall condition of tenseness or stress.

Figure 18 of factor seven represents stress or tenseness in crew members.



This factor represents stress or tenseness.

Figure 18. Factor Seven

The following factors eight through fourteen do not require graphs for explanation. These factors had groupings of only two or less questions. The complexity of analysis is therefore reduced adequately without the aid of a graphic representation. The same measures of loading and t

statistic will be represented by their numeric values within the discussion for the factor.

9. <u>Factor Eight</u>

The best description for this factors as in most of the factors that will follow is the name of the questions. Factor eight had loadings of 0.82 for the question Q4 corners cut (flight) and 0.79 for Q3 corners cut (preflight). The t statistics were 3.22 for question four and 3.94 for question three. The results of this factor can be interpreted as reduction in work load due to fatigue. The question corners cut represents a skipping of some procedures required in a technical job. These procedures that are skipped are normally not essential task but are required for a thorough knowledge of equipment readiness or reproduction of tactical and analytical performance during flight. The difficulty that can arise form a "cut corner" can be severe. Normally these essential task are accomplished but mission effectiveness and possibly safety can be affected by a lack of thoroughness. The general assumption of a loss of control over thoroughness can be assumed to be significantly affected by fatigue.

The exact nature of the importance of the lack of control over thoroughness is associated with probabilities of unsafe acts occurring. The probability is high that these levels of corners cut are not going to cause a degraded mission or lack of safety. The affect of fatigue

on thoroughness of an untrained crew member may not have this same high probability. A highly trained and experienced crew member will probably not cut the wrong corner due to a very good technical and procedural knowledge of essential requirements. An untrained and inexperienced crew member does not have the knowledge base required to make a correct judgement about what if any corner can be cut. Fatigue increases the tendency to cut corners for the crew in general and critical errors may occur if a lack of training or knowledge exist in one of these crew members. This could easily lead to an unsafe condition and caution is in order for individuals that are experiencing fatigue due to this lack of thoroughness.

10. Factor Nine

The classification of factor nine is vision. A factor loadings of 0.84 for Q33 vision (sharpness or clearness), 0.79 for Q34 vision (night) and 0.38 for Q35 vision (ability to recognize things). The t statistics were 10.72 for Q33, 8.76 for Q34 and 9.45 for Q34. Vision degradation is highly significant for crew members in all three vision questions . This factor represents the effect that fatigue and anoxia has on vision. McFarland (1932, pp. 1-35) using a rebreathing apparatus made some of the first attempts to establish the relationship of anoxia with vision impairment. Fatigue may also be a part of these highly significant degradations in vision but anoxia is probably

the primary source of these high t statistics. The high altitude operations out of Keflavik Iceland had higher t statistics than the some what lower altitude operations out of Adak Alaska. Both aviation Environments require high altitude operations. The aircraft are identical in both locations with pressurization greater than an equivalent of 10,000 feet above sea level. Oxygen is used by the flight station prior to landing at the aircraft's destination. This procedure becomes more important as the possibility of fatigue becomes more apparent. Anoxia can be overcome by greater concentrations of oxygen. If fatigue is also affecting vision it is important to overcome the anoxia to minimize risk that fatigue may be imposing.

11. <u>Factor Ten</u>

This factor represents the effect of sleep on memory. Factor Ten loaded at 0.85 for Q8 how many hours sleep and 0.41 for Q41 ability to recall information. The t statistic for Q8 was 1.01 and for Q41 was 9.32. The question how many hours sleep was not statistically significant. These questions did group together and the question, ability to recall information, had a high level of significance. The conclusion that can be drawn from this is that the amount of sleep that one receives is important to the ability to recall information.

12. Factor Eleven

This factor can be classified as circumstantial control over fatigue. This factor loaded at 0.77 for Q21, how aware of fatigue were you, and 0.61 for Q26, conflicts (interpersonal). The t statistic for Q21 was 3.3 and for Q26 was 4.7. The amount of awareness of fatigue is associated with the amount of conflicts. The awareness of fatigue can be caused by greater sensitivity to fatigue's effects. This sensitivity may also increase the awareness of conflicts or cause more conflicts to take place. The highest probability is that there is a combination of a greater number of conflicts and a greater sensitivity to those conflicts. The awareness in this case may be a positive or a negative attribute. The information available in this data does not distinguish between positive or negative only the change from before and after.

This factor may be significant in explaining the view points and perspectives involved in internal reserves and their relationship to the use of external resources. The persons sensitivity level to fatigue may increase conflicts when the use of external resources becomes necessary. This sensitivity level may also be no more than a mental state which becomes more sensitive to conflicts as awareness of fatigue is increased.

13. <u>Factor Twelve</u>

This factor represents the degradation in information transfer between personnel and willingness to act on instructions. The factor loaded at 0.80 for Q40, amount the instructions needed to be repeated, and 0.61 for Q44, how responsive to duties were others. The t statistic for Q40 was 4.07 and for Q44 was 4.20. These questions were substituted for leadership and "followship" ability from the initial survey. The significance and the high loading of both questions makes the questions of uniform importance in explaining the factor grouping. The transfer of instructions into action was degraded due to fatigue. This degradation represents a slowing of normal crew processes and a greater difficulty in controlling the overall evolution. These two questions can be used to assess how well a crew is functioning with regard to communication and responsiveness to communications.

14. <u>Factors Thirteen and Fourteen</u>

These factors are self explanatory. Both loaded on only one question per factor. Factor thirteen loaded at 0.76 on Q23 how much fatigue did you observe in others and had a t statistic of 4.63. Factor fourteen loaded at 0.82 on Q17, how safe did you feel and had a t statistic of 7.07. Factor thirteen indicates that fatigue was physically manifested in a noticeable way. Factor fourteen demonstrates a highly significant lowering of a feeling of

safety due to the increased fatigue levels and difficulties fatigue imposes. Both factors are significant and both are important to an evolution.

15. Communality Estimates

Table 15 is the amount of variation explained by each factor. The total final communality estimates equals 34.9.

TABLE 15

VARIATION EXPLAINED BY EACH FACTOR FOR UNITS 2 AND 3

Factors	Variance explained by each factor (Any number over one is considered significant)
Factor 1	4.379
Factor 2	4.271
Factor 3	2.803
Factor 4	2.415
Factor 5	2.391
Factor 6	2.288
Factor 7	2.285
Factor 8	2.272
Factor 9	2.204
Factor 10	2.176
Factor 11	2.030
Factor 12	1.907
Factor 13	1.883
Factor 14	1.608

16. Summary

There are many indications that Unit one is experiencing a high level of external reliance. This is illustrated by the large number of factors which contained questions that indicate a non resolution of problems due to fatigue. Fatigue seems to operate much like Schonpflug (1983, pp. 299-327) predicted. Fatigue effects internal demand through increased use of reserve energy. The higher the level of fatigue and the longer the period that fatigue persists, the more shifts in performance are necessitated through various coping strategies or a reduction in aspiration. These reductions in aspiration or coping strategies can cause a feed back of non resolved problems into the system of regulatory behavior. At this general point in the cycle supply is starting to exceed demand. This general point is not very discernable. The feedback of non resolved problems is relative to the environmental situation, the amount of competence of the individual, the energy reserve the individual has available, the amount of energy the individual can produce and the inventiveness that the individual has available to alter and make the correct coping strategies. This list can become even longer when one considers the external resources an individual can utilize.

It is not productive to attempt to determine at what point an individual is effected by fatigue or to the point

of being unsafe to fly. It is productive to give to that individual a list of symptoms and a basic understanding of the definition of fatigue.

Schonpflug's (1983, p. 321) regulatory model is extremely adaptable to the problem that fatigue presents and its interpretation. The primary caution to a crew member should be that non resolved problems are not just determined by a failure in competence but instead by a system of regulatory behavior. Fatigue is only a part of this system but if fatigue is present and when 100 percent performance is required then one must look at some objective indicators to ensure safety. These indicators are:

1. A greater than normal amount of external reliance.
2. A persistent difficulty in problem resolution or a feeling of being overwhelmed.
3. Difficulties in coping caused by too much or not enough emphasis on problems or tasks.
4. An ever decreasing aspiration toward task performance to the point of non resolution of problems which persist. (Schonpflug 1983, pp. 315-319)

Stress is related to fatigue and may be the primary component that segregates fatigue from sleep debt or circadian desyncronization. Stress is linked to behavioral tasks that require high energy demand. Fatigue is likely to be the result of over extension of energy pools to the point of low reserve or exhaustion of reserves. The factors above give some indication of the relationships that occur when energy pools are low or exhausted. When internal demand

exceeds supply the result is a greater reliance on external resources, a lowering of aspiration, a lowering of activation and a difficulty with coping. It seems very likely that Schonpflug (1983, p. 321) has built a model that was sought by Bartley and Chute (1947, p. 47), Cameron (1973, p. 646) and the many investigators that have done basic research on areas that relate to fatigue. Schonpflug's model of regulatory behavior is a marked advance toward placing fatigue into a system of behavior that not only clarifies the definition of fatigue but also allows the assessment of fatigue to proceed in a logical progression.

APPENDIX A

SAM FORM 136

Name and Grade Time/Date

INSTRUCTIONS: Make one and only one check mark for each of the ten items. Think carefully about how you feel RIGHT NOW.

STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7. PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

APPENDIX B

SAM FORM 202

SUBJECTIVE FATIGUE

(Circle the number of the statement which describes how you feel RIGHT NOW.)

1 Fully Alert; Wide Awake; Extremely Peppy

2 Very Lively; Responsive, But Not At Peek

3 Okay; Somewhat Fresh

4 A Little Tired; Less Than Fresh

5 Moderately Tired; Let Down

6 Extremely Tired; Very Difficult to Concentrate

7 Completely Exhausted; Unable to Function Effectively; Ready to Drop

COMMENTS

WORKLOAD ESTIMATE

(Circle the number of the statement which best describes the MAXIMUM workload you experienced during the PAST HOUR. Estimate and record the number of MINUTES during the past hour you spent at this workload level.)

MINUTES

1 Nothing to do; No Systems Demands

2 Little to do: Minimum Systems Demands

3 Active involvement Required, But Easy to Keep Up

4 Challenged But Manageable

5 Extremely Busy; Barely Able to Keep Up

6 Too Much to do; Overloaded; Postponing Some Tasks

7 Unmanageable; Potentially Dangerous; Unacceptable

COMMENTS

APPENDIX C

QUESTIONNAIRE ON CREW FATIGUE PERIOD
4 JUNE TO 6 JULY 1985

NAME:

CREW:

POSITION:

Circle the following. First column before Flap, second column 100+ hours into Flap.

		maximum									minimum
1. Motivation level:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		maximum									minimum
2. Attitudes:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
	nothing bothers me/everything bothers me										
3. Tolerance level:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		numerous									none
4. Changes in character:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		numerous									none
5. Corners cut:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		less work									more work
6. Desire to do work:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10

			better									same
7.	Ability on job: ABLJ	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			better									same
8.	Alertness: ALRT	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			better									same
9.	Endurance: ENDR	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			high									lower
10.	Need to assist others: ASS	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			high									lower
11.	How much fatigue: FTGI	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			excellent									no sleep
12.	How well did you sleep: WLSP	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			hours per 24 hr. period									
13.	How many hours: HRSS	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			easy									couldn't sleep
14.	If interrupted during sleep, how easy was it to go back to sleep: INTS	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10
			very rested									very tired
15.	How rested did you feel after sleep period: AFTS	Before:	1	2	3	4	5	6	7	8	9	10
		After:	1	2	3	4	5	6	7	8	9	10

16. What contributed most to fatigue for each flight:		most									least
RAPID TURNAROUND:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		most									least
LENGTH OF FLAP:	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		safe									unsafe
17. How safe did you feel: SFFL	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		needed									not needed
18. Aircrew support by station facility: SPFC	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		more									less
19. Brief/debrief impact on crew rest: BFDF	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
		numerous									none
20. Changes required to overcome mistakes or lower alertness: CGOV	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10
21. Would flights cause greater or less fatigue if flown at the same time of a 24 hour day:			greater								less
		very									not at all
22. How aware were you of fatigue: AWRF	Before:	1	2	3	4	5	6	7	8	9	10
	After:	1	2	3	4	5	6	7	8	9	10

			high level · · · low level
23.	How much fatigue did you observe in others: HMFG	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			more · · · less
24.	How much extra attention to work was necessary to ensure safety: EASF	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			more · · · less
25.	Amount of attention to detail required to do work: ATDL	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			excellent · · · poor
26.	Crew coordination: CRCO	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			excellent · · · poor
27.	Personal coordination abilities: PCDA	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			more · · · less
28.	Conflicts: CNFL	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			excellent · · · poor
29.	Control of station and duties: CTSD	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			excellent · · · poor
30.	Logs and records keeping: LSRK	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10

			excellent poor
31.	Airmanship: ARSP	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			improved degraded
32.	Vision: VISN	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			improved degraded
33.	Leadership ability: LDSA	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			improved degraded
34.	Followship ability: FLWA	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			improved degraded
35.	Crew inter-actions: CRIN	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			improved degraded
36.	Sense of humor: SNHM	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			high low
37.	Energy level: EGLV	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			ahead behind
38.	Problems: PBLM	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10
			ahead behind
39.	Power curve: PRCV	Before:	1 2 3 4 5 6 7 8 9 10
		After:	1 2 3 4 5 6 7 8 9 10

Remarks or suggestions:

Observations:

Incidents of interest during Flap. (Unclass)

APPENDIX D

QUESTIONNAIRE ON CREW FATIGUE PERIOD
FEBRUARY, MARCH, APRIL 1987

Personal Factors:

Position: SS1 SS2 SS3 ORD FE IFT OBS PPC 2P 3P TACCO NAV
(circle one) Other______________

Time in position_________ Total time in airframe__________

Age_______ Height________ Weight________

Hours flown in the preceding: 30 day period_______% ASW______
90 day period_______ (approx OK)

Physical condition on the Navy physical fitness test:
(circle one)

outstanding excellent good satisfactory minimum standard

Exercise time per day:____________

Survey:

The following questions require a thoughtful and honest assessment of personal and environmental conditions.

This is an example of how responses should be given:

		excellent						poor
1. Appetite:	Before:	1	2	3	4	5	6	7
	After:	1	2	3	4	5	6	7

The first scale represents your status before the flight period began. The second scale represents your status after the flight period. Simply circle the number that represents your status on a scale from one to seven on each scale. Please note the descriptive words above the scale before answering the question (these words represent the extremes of the scale).

---

		maximum						minimum
1. Motivation level: (desire to do job)	Before:	1	2	3	4	5	6	7
	After:	1	2	3	4	5	6	7

---

		nothing bothers me	everything bothers me
2. Tolerance level: (inter-personal)	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		numerous	none
3. Corners cut: (preflight)	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		numerous	none
4. Corners cut: (during flight)	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		very balanced	not at all
5. Balanced diet:	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		excellent	poor
6. Attitude: (your feeling)	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		better	worse
7. Ability on job: (flight operations)	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		one hour	ten hours
8. How many hours of sleep:	Before:	1 2 3 4 5 6 7 8 9 10	
(quantity)	After:	1 2 3 4 5 6 7 8 9 10	
		better	worse
9. Endurance: (sustain activity)	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	
		better	worse
10. Alertness: (ability to be	Before:	1 2 3 4 5 6 7	
vigilant)	After:	1 2 3 4 5 6 7	
		higher	lower
11. Need to assist others:	Before:	1 2 3 4 5 6 7	
	After:	1 2 3 4 5 6 7	

			excellent						poor
12.	How well did you sleep: (quality)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			higher						lower
13.	How much cumulative mental fatigue:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			higher						lower
14.	How much cumulative physical fatigue:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			easy				couldn't get back to sleep		
15.	If interrupted how easy was it to go back to sleep:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			very rested					very tired	
16.	How rested did you feel after sleep period:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			safe						unsafe
17.	How safe did you feel: (flight operations)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			numerous						none
18.	Changes required to overcome mistakes: (flight operations)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			very much						none
19.	How much did flights at different times of the day fatigue you:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			higher						lower
20.	How tense or uptight: (stress)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7

			very						not at all
21.	How aware of fatigue were you:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			improved						degraded
22.	Ability to maintain attention to detail:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			high level						low level
23.	How much fatigue did you observe in others:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			excellent						poor
24.	Crew coordination: (group interaction)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			excellent						poor
25.	Ability to separate required from not required information:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			more						less
26.	Conflicts: (inter-personal)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			excellent						poor
27.	Coordination abilities: (physical)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			more						less
28.	How much extra attention to work was necessary to ensure performance:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			improved						degraded
29.	Interest in job: (flight operations)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			more						less
30.	How important was your job to you: (flight operations)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7

		excellent						poor
31. Control of station and duties:	Before:	1	2	3	4	5	6	7
(flight operations)	After:	1	2	3	4	5	6	7
		excellent						poor
32. Airmanship: (ability to set and	Before:	1	2	3	4	5	6	7
maintain priorities)	After:	1	2	3	4	5	6	7
		improved						degraded
33. Vision: (sharpness,	Before:	1	2	3	4	5	6	7
clearness)	After:	1	2	3	4	5	6	7
		improved						degraded
34. Vision: (night)	Before:	1	2	3	4	5	6	7
	After:	1	2	3	4	5	6	7
		improved						degraded
35. Vision: (ability to	Before:	1	2	3	4	5	6	7
recognize things)	After:	1	2	3	4	5	6	7
		excellent						poor
36. Logs and record keeping:	Before:	1	2	3	4	5	6	7
	After:	1	2	3	4	5	6	7
		improved						degraded
37. Sense of humor:	Before:	1	2	3	4	5	6	7
	After:	1	2	3	4	5	6	7
		excellent						poor
38. Ability to cope with a lot of	Before:	1	2	3	4	5	6	7
information at one time:	After:	1	2	3	4	5	6	7
		high						low
39. Energy level: (physical)	Before:	1	2	3	4	5	6	7
	After:	1	2	3	4	5	6	7
		increased						decreased
40. Amount that instructions	Before:	1	2	3	4	5	6	7
needed to be repeated:	After:	1	2	3	4	5	6	7

			excellent						poor
41.	Ability to recall information:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			always						never
42.	Eating meals at the normal time of day:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			improved						degraded
43.	Crew interactions: (inter-personal)	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			very slow						very fast
44.	How responsive to duties were others:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			very						not at all
45.	How coordinated were others:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7
			very						not at all
46.	How efficient were others in performing tasks:	Before:	1	2	3	4	5	6	7
		After:	1	2	3	4	5	6	7

The following questions require only a present time response:

		very much						none
47.	How much fatigue did flights have with minimum crew rest between them:	1	2	3	4	5	6	7
		very much						none
48.	How much fatigue did the length of flap have:	1	2	3	4	5	6	7

Remarks:

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